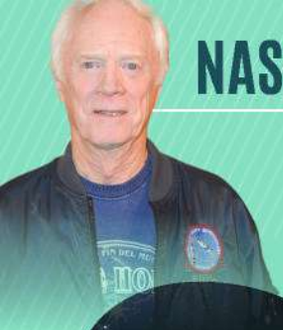


NASA'S RUSTY SCHWEICKART ON THE FIRST APOLLO SPACEWALK

ALL ABOUT SPACE™

ISSUE 147
SEPTEMBER 2023

DISCOVERED

STRANGE NEW WORLDS

THE EXOTIC EXOPLANETS THAT DEFY THE LAWS OF PHYSICS

DAYTIME ASTRONOMY

OBSERVER'S GUIDE TO THE SUN AND MORE

USER MANUAL

MAUNA KEA'S SUBARU TELESCOPE

FUTURE
ISSUE 147

HEROES OF SPACE: CARL SAGAN / THE STAR WITH TWO FACES
NIGHT-SKY TARGETS / REVIEWED: VAONIS VESPERA OBSERVATION STATION

CELESTRON®

OVER 60 YEARS
OF INNOVATIVE TECHNOLOGY

DISCOVER MORE
StarSense Explorer Dobsonian

StarSense Explorer™

The patented technology in Celestron's StarSense Explorer telescope has revolutionized astronomy. Harnessing the power of your smartphone and a Lost In Space Algorithm (LISA) like the ones used on orbiting satellites, the StarSense Explorer app guides you to celestial objects in real-time as you move the telescope. Our engineers have been listening to your feedback, and we're proud to bring the power of StarSense Explorer to four new telescopes.

NEW! StarSense Explorer 12" Dobsonian
Our largest-ever Dobsonian telescope reveals a whole new level of depth and detail for the ultimate StarSense Explorer experience. With its massive parabolic primary mirror and highly reflective Celestron XLT coatings, this reflector delivers the brightest, most detailed views in the StarSense Explorer line. Its ultra-sturdy Dobsonian base features an ergonomic carry handle and eyepiece rack.

NEW! StarSense Explorer Tabletop Dobsonians
Bring the star party with you. Don't be fooled by these tabletop Dobsonians' small stature—they offer plenty of light-gathering ability and a parabolic mirror to bring out detail in all the best celestial objects. It all sits on a portable, tabletop base that's ready to go anywhere. Includes two Kellner eyepieces, the StarSense dock, and a StarPointer finderscope.

StarSense Explorer 12"
RRP £1299.99

114mm RRP £299.99

130mm RRP £399.99

150mm RRP £499.99

Have any questions? Contact us:
Email: **enquiries@celestron.com**

@celestronuk
SCAN THE QR to discover more!

WELCOME

ISSUE 147

SCAN HERE TO GET OUR DAILY NEWSLETTER

© NASA/JPL-Caltech

I remember when the very first exoplanet was confirmed. It was 1992, and the now-decommissioned Arecibo Observatory had revealed a brand-new terrestrial world – and later a collection of others – around pulsar PSR B1257+12. But it wasn't just the minds of the discoverers that ran wild when working out what these far-flung planets were like on the surface, it was also the public. The discovery of worlds beyond our Solar System really fired the imagination. To date, almost 6,000 exoplanets have been found using various techniques and missions. This issue, we take you on a tour of 20 of the strangest in our cover feature – from those with exotic weather to others that truly defy physics.

I'll leave you to enjoy the issue, but before I do, don't forget you can get amazing offers on **All About Space** when you subscribe – see the right-hand side of this page for further details! Whether you're due a renewal or you're a first-time subscriber, we'll be delivered directly to your door, and you'll save on the cover price, too.

GEMMA LAVENDER
Editor

46 Subscribe to All About Space today and you'll receive

- ✔ **Great savings off the cover price**
- ✔ Every issue delivered straight to your door or digital device before it arrives in the shops
- ✔ **Exclusive subscriber-edition covers**

ALL ABOUT SPACE
ISSUE 148
ON SALE 5 OCTOBER

INSIDE

16 STRANGE NEW WORLDS

LAUNCHPAD

06 News from around the universe

FUTURE TECH

24 Space factories
Could we 3D print parts and equipment in space?

INTERVIEW

26 Rusty Schweickart
The retired NASA astronaut tells **All About Space** how a jammed camera during a spacewalk changed his life

FOCUS ON

30 A 'meteorite' that struck a French woman was just a regular Earth rock

32 Sci-fi night sky
Look out into the universe and you'll recognise some of its members have played a part in the works of science fiction

FOCUS ON

40 'Hidden' photons could shed light on mysterious dark matter

USER MANUAL

42 Subaru Telescope

INSTANT EXPERT

48 Planet formation: Is it turbulent or tranquil?
How gaseous and rocky bodies form around young stars

FOCUS ON

50 The James Webb Space Telescope spies water near the centre of a planet-forming disc

52 Next giant leap
We've gone from biplanes to Falcon 9 in a century. What will the next 100 years bring?

FOCUS ON

58 Our infant Solar System may have survived a nearby supernova

60 The two-faced star
With one side helium and the other hydrogen, the white dwarf Janus is baffling astronomers

FOCUS ON

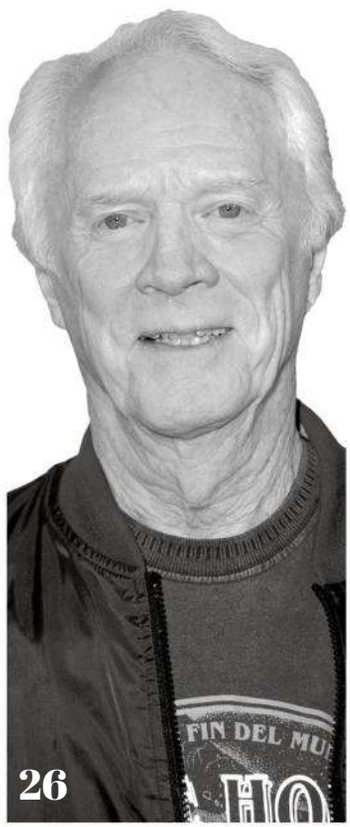
66 Stars with powerful magnetic fields could narrow the search for alien life

68 Ask Space
Your questions answered by our panel of experts

FOCUS ON

72 An ancient star that crashed a hot, young star party could solve a Solar System mystery

74 Daytime astronomy
Forget staying up late, **All About Space** shows you how to get stuck into observing without waiting until the small hours



STARGAZER

80 What's in the sky?

82 Planetarium

84 Month's planets

86 Moon tour

87 Naked eye and binocular targets

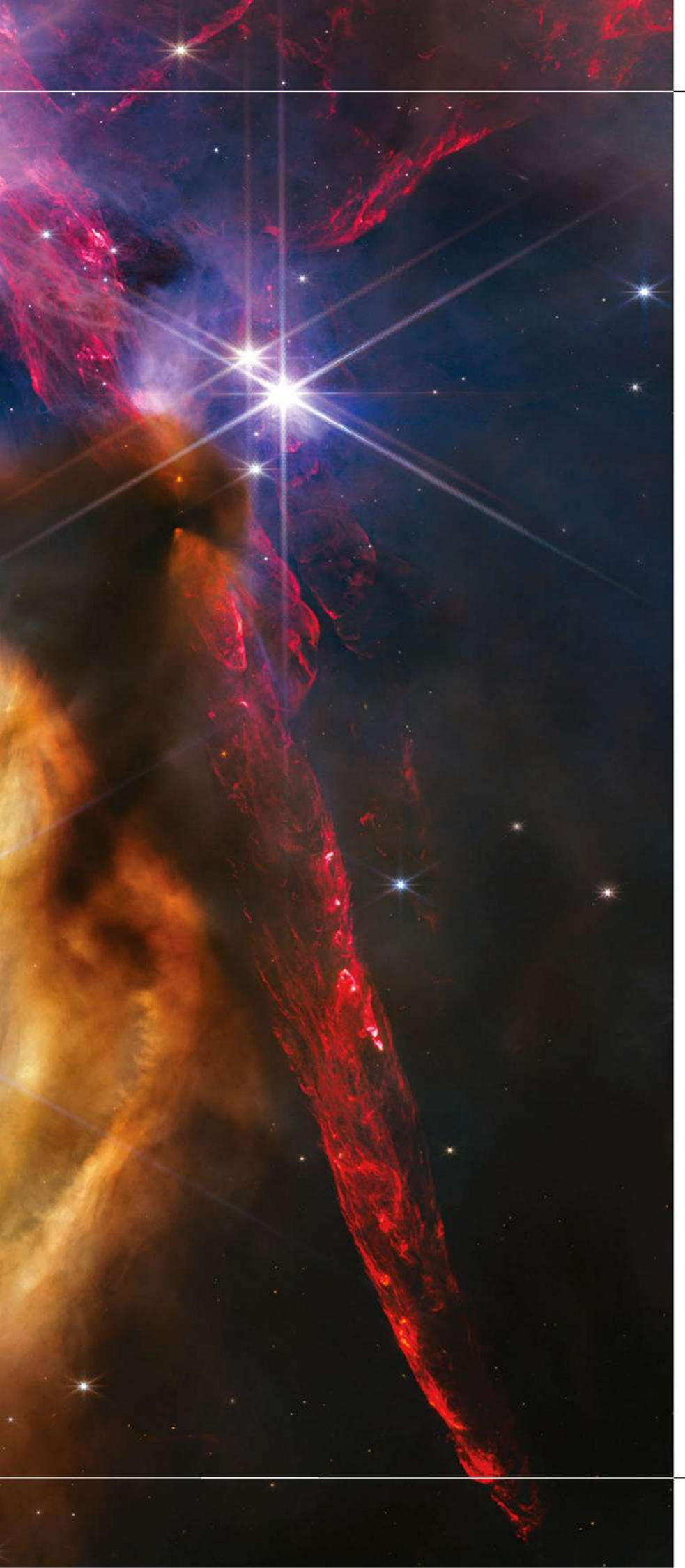
88 Deep sky challenge

90 The Northern Hemisphere

92 Review

96 In the shops

WIN!
CELESTRON SKYMASTER 20x80
15



12 July 2023

Webb's first birthday photo

One year after kicking off operations, the James Webb Space Telescope has already revolutionised our view of the universe. And to celebrate Webb's first birthday, scientists have released one of the telescope's most gorgeous images yet. The new picture is a close up of Rho Ophiuchi, a star-forming region roughly 390 light years away in the constellation of Ophiuchus. This dense cloud complex consists of two major regions thick with dust and gas, each of which acts as a star factory. In the image, Webb captured about 50 young stars shortly after their birth. Each is similar in size to the Sun, and a few have the telltale shadows of protoplanetary discs that will one day condense into planets.

Webb is equipped with four main instruments: the Near-Infrared Camera (NIRCam), the Near-Infrared Spectrograph (NIRSpec), the Mid-Infrared Instrument (MIRI) and the Fine Guidance Sensor/Near Infrared Imager and Slitless Spectrograph (FGS/NIRISS). These powerful instruments enable the telescope to peer deep into outer space and pick up the traces of light left over from the universe's first stars. They've also allowed Webb to analyse the atmospheric composition of faraway exoplanets, detect the oldest organic molecules and even piece together the structure of the cosmic web that connects galaxies.

"With a year of science under our belts, we know exactly how powerful this telescope is and have delivered a year of spectacular data and discoveries," Jane Rigby, Webb senior project scientist at NASA's Goddard Space Flight Center, said. But even with all the data it's collected in the past year, Webb is far from finished. The mission is scheduled to run for at least another decade, and scientists are eagerly planning the telescope's next moves. "We've selected an ambitious set of observations for year two," Rigby said. "Webb's science mission is just getting started."

© NASA

24 July 2023

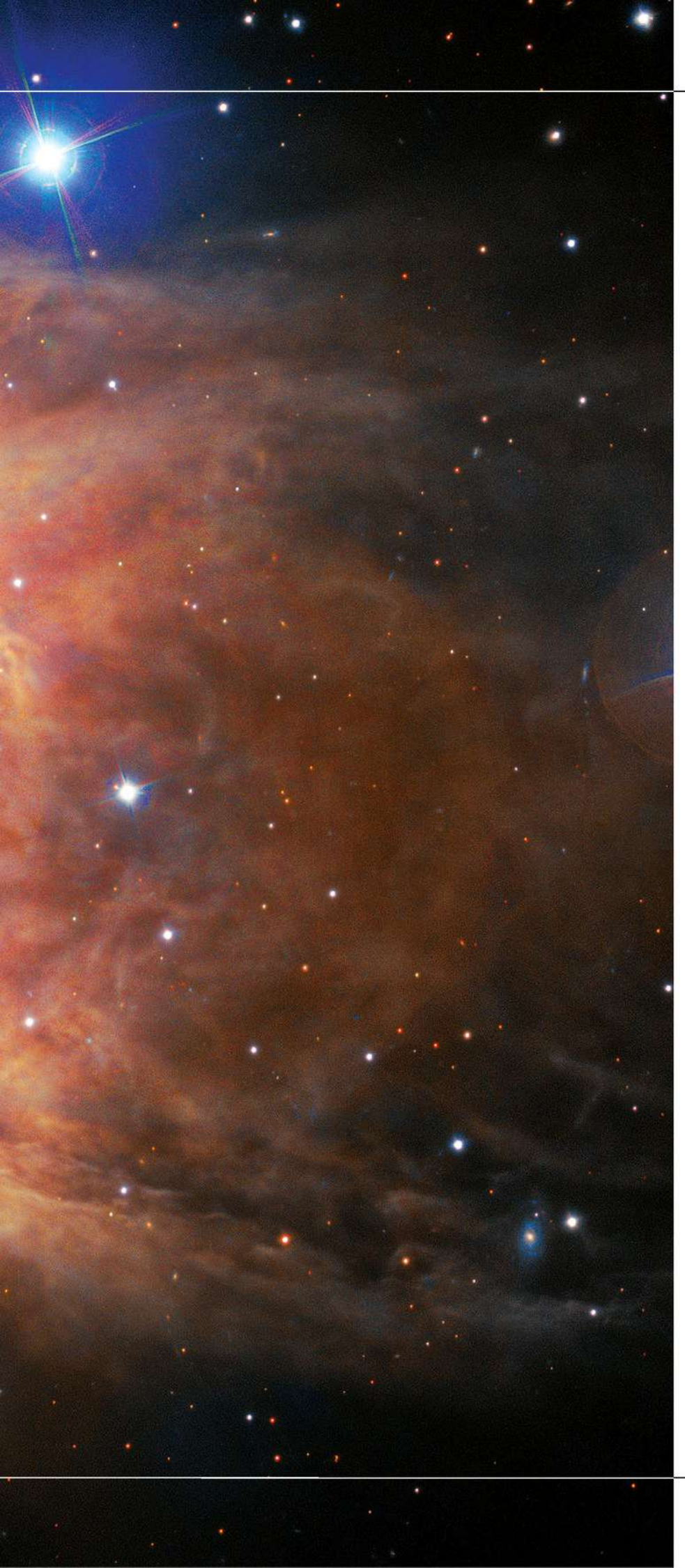
A bright galaxy with a violent past

A new image from the Hubble Space Telescope captures a stunning head-on view of a distant galaxy with tightly wound spiral arms. The spiral galaxy, known as UGC 12295, lies approximately 192 million light years from Earth in the constellation of Pisces. While the galaxy appears to bask leisurely in space, the Hubble observations show it recently hosted a stellar explosion, also known as a supernova, said officials at the European Space Agency (ESA). "Despite appearing as an island of tranquillity in this image, UGC 12295 played host to a catastrophically violent explosion – a supernova – that was first detected in 2015," ESA officials said. "This supernova prompted two different teams of astronomers to propose Hubble observations of UGC 12295 that would sift through the wreckage of this vast stellar explosion."

When a massive star reaches the end of its life, it dies in a dramatic explosion called a supernova. Supernovae are incredibly luminous and powerful, blasting large amounts of material into space. As a result, they're believed to be responsible for forging many of the elements found on Earth. Using Hubble's Wide Field Camera 3, astronomers examined the debris left behind by the supernova explosion in UGC 12295, along with supernovae in neighbouring sites. Observations of supernova remnants can help astronomers better understand the evolution of matter in the universe and the star systems that fuel such cosmic explosions. "Hubble's keen vision can reveal lingering traces of these energetic events, shedding light on the nature of the systems that host supernovae," ESA officials said.

The new image from Hubble, which is a joint mission between the ESA and NASA, captures the galaxy directly face-on, revealing two distinct spiral arms that extend from a bright central bar. Additional fainter arms branch off from these, studded with bright-blue patches of star formation. Smaller, more distant galaxies – likely home to supernovae, too – can be seen in the background of the image.

© NASA



13 July 2023

A red giant in its jug-shaped death throes

The stellar wreckage left by the death throes of a giant red star takes the appearance of an overflowing cosmic jug in a stunning new image. The observation, made by the Gemini South telescope, part of the International Gemini Observatory, shows a cloud of gas and dust shed by a star as it swelled up during its red giant phase and created a rare double-lobed planetary nebula. The nebula, located around 1,200 light years away in the direction of the constellation of Carina, may also contain the remains of a companion star to the red giant that was shredded long ago.

The glowing, orange structure resembles an old English pottery drinking vessel, a Toby Jug, which takes the gnome-like form of a seated person with cartoonish features. As a result, this planetary nebula, officially designated IC 2220, is nicknamed the Toby Jug Nebula. At the heart of the double-lobed Toby Jug planetary nebula is the red giant star HR3126, which at just 50 million years old is considerably younger than the 4.6-billion-year-old Sun. HR3126 reached its red giant phase considerably more rapidly than the Sun because it is five times the mass of our star, which means it burned through its hydrogen much more rapidly than the Sun does. The dying red dwarf star continues to expel gas causing the material that surrounds it, which can take a variety of shapes, to glow brightly. This glowing envelope of gas is a planetary nebula.

Beyond its aesthetic value, this double-lobed planetary nebula is of great value to scientists studying stellar evolution. That's because this particular end-of-life phase of red giant stars is brief, and the planetary nebulae that form around them are short-lived, lasting around 20,000 years, and are thus rarely sighted. The somewhat-rare double-lobed or bipolar structures like that of the planetary nebula illuminated by HR3126 are believed to be the result of interactions between a red giant star and a stellar companion. Previous observations of IC 2220 have failed to turn up a companion star by HR3126, however. This absence suggests to astronomers that the companion star that once helped shape the hourglass-like form of IC 2220 has now been shredded, with its material now dispersed in the nebula.

© NASA

Artificial intelligence is helping scientists reveal star ages

Reported by Tariq Malik

A new machine-learning algorithm aims to provide improved measurements of stellar ages, allowing astronomers to better model how stars evolve. The algorithm is an AI version of a project called EAGLES, which stands for Estimating Ages from Lithium Equivalent Widths. EAGLES uses the lithium abundance of stars to determine their age. Previously this work had been done by fitting data to graphs. With surveys producing more and more data, this task has grown time-consuming and complex, so an AI has been written to take on the job.

All stars are born containing the same proportion of lithium, but as they age they lose this lithium at different rates depending on their masses, and therefore temperatures – the more massive the star, the hotter the temperature, which astronomers use as a proxy because they can't measure the mass of the star directly. The hotter a star, the greater the rate of convection in that star's outer layers and the more this churns up the lithium on a star's surface. As lithium sinks into a star's interior, it's converted into two helium nuclei by fusing with a proton. The result is that the lithium is increasingly depleted as time goes by. Therefore, the abundance of lithium observed in a star, coupled with the star's temperature, should together provide a measure of that star's age.

Traditionally, astronomers measure a star's age with lithium by looking at the strength of the lithium spectral line in a star's spectrum – which is what 'equivalent widths' in EAGLES' name refers to – then trying to fit it to models of stellar evolution. Not only is this method "difficult to do and requires a lot of work," but scientists also want to expand beyond lithium abundances to include other stellar properties that can indicate age as well, said George Weaver of Keele University. Weaver and his supervisor, Robin Jeffries, have thus introduced AI to take on some of the workload, particularly when handling lots of information covering the other age indicators coming in from big all-sky surveys. It's possible AI can find previously undiscovered relationships in stars' data.

Astronomers can more easily measure the relative ages of stars in star clusters because a cluster's stars were all born at the same time, meaning they can be directly compared based on how they have evolved. Weaver and Jeffries sampled 6,000 stars from a total of 52 clusters observed by the European Space Agency's Gaia mission. Then they trained the EAGLES algorithm on the selected stellar bodies. "A stellar evolution model tells you what a star should look like as a function of age," Jeffries said. "If we have stars whose ages we know, that's very helpful when comparing to stellar evolution models."

AI is being used increasingly often in astronomy as a method of handling big data, and EAGLES is no different. It will soon be applied to two deep surveys, beginning with the WHT Enhanced Area Velocity Explorer (WEAVE) survey on the William Herschel Telescope at La Palma this year, and continuing in the 4-meter Multi-Objects Spectrograph Telescope (4MOST) survey on the Visible and Infrared Survey Telescope for Astronomy (VISTA) at the European Southern Observatory in Chile in 2024. "These are two major spectroscopic surveys that will cover essentially the whole sky and take spectra of tens of millions of stars," said Jeffries. "They will produce lithium equivalent widths, temperatures, rotation rates and measurements of magnetic activity. We then hope to provide the age, which is an essential part of doing these surveys, which is to try and reconstruct the star-formation history of various populations of stars in the galaxy."

Weaver hopes to eventually expand EAGLES even further by including age indicators besides lithium abundance. Some options include barium abundance, magnetic activity and stellar rotation rates. "You can put in as much or as little data as you have, and the model will do its magic," said Weaver. "At the minute we're just expanding those additional age indicators."

The EAGLES neural network does have one significant limitation, however. It can only accurately measure the ages of stars up to about 6 billion years old, which is the age of the oldest cluster the algorithm was trained on. Furthermore, the oldest stars in the universe tend to all have the same amount of lithium."You wouldn't get an age discriminator out of lithium for the oldest stars," said Jeffries. "It works best for young stars."

"All stars are born containing the same proportion of lithium, but as they age they lose this lithium at different rates depending on their masses"

China keeps its eye on NASA's budget uncertainty

Reported by Andrew Jones

China is watching developments surrounding NASA's budget and anticipating how it could affect programs and US leadership in space. The White House's federal budget request for fiscal year 2024 allocated $27.2 billion (£21.3 billion) to NASA, representing a seven per cent increase over what it received in 2023. Some of the major objectives outlined in the budget are the Artemis program that aims to return astronauts to the Moon, the Mars Sample Return program, continuing to make new scientific discoveries in the Solar System and beyond, maintaining a long-term presence in low-Earth orbit and advancing US leadership in innovation. But draft bills from the US Congress House and Senate appropriators would give NASA slightly less than its 2023 budget instead of the requested boost. The ambitious Mars Sample Return program is also in jeopardy after the Senate raised questions over its budget.

China's space sector is keeping its eye on developments. A recent article in the *Chinese Journal of Space Science*, authored by researchers at the Institutes of Science and Development under the Chinese Academy of Sciences (CAS), maps out key issues and possible repercussions. The report states that severe inflation will offset any NASA budget growth, reducing the impact of a potential seven per cent increase or compounding cuts. Furthermore, the report claims that Congress is increasingly divided, with a wide gap between Republicans and Democrats in terms of budget spending priorities and no clear path to compromise. The article looks at two scenarios for NASA based on two proposals being considered by Republican leadership in the House of Representatives. The first, seeing a reduction of discretionary spending of the US government to the level of fiscal year 2022, would not have a particularly serious impact on NASA in the long term. It would significantly delay the Artemis IV mission, and the procurement of a second Artemis lunar lander would be cancelled. The Mars Sample Return mission, the Deep Atmosphere Venus Investigation of Noble gases, Chemistry and Imaging (DAVINCI) mission to Venus and the Dragonfly mission to Saturn's moon Titan would also be delayed, with further missions cancelled or postponed.

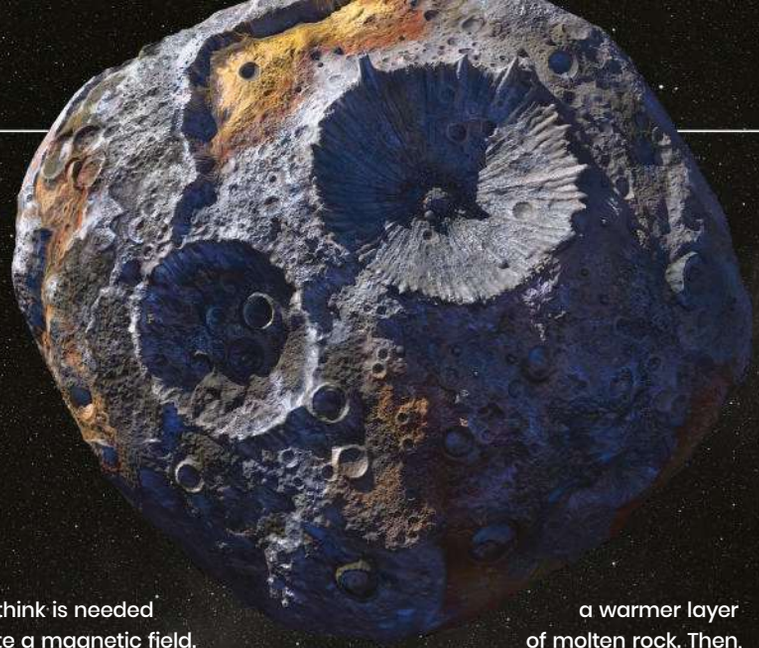
A second scenario – a cut of 22 per cent compared to 2023 funding levels – could have irreversibly damaging effects on NASA programs, resulting in multiple missions being postponed or cancelled. Artemis IV would be substantially restructured or terminated, including elements of the upgraded Space Launch System (SLS) and Gateway programs. Such budget cuts would also delay or cancel Mars Sample Return, DAVINCI, Dragonfly and others, including several future astrophysics missions, notably the Nancy Grace Roman Space Telescope and the Interstellar Mapping and Acceleration Probe (IMAP).

Other implications include a reduction in the number of cargo missions to the International Space Station (ISS) and delays in the development of both the ISS deorbiting space tug and commercial successor missions to the space station. China has its own space station, Tiangong, planned crewed lunar missions, plans for a Moon base and its own Mars sample-return project. The country is also facing its own economic challenges, but its space budget and policy processes are very opaque. Respective progress on these major projects will have impacts on global space leadership.

HOW IT WORKS
subscription offer
FROM £2.50 PER ISSUE!
PRINT
£3.83 PER ISSUE
DIGITAL
£2.50 PER ISSUE
PRINT & DIGITAL
£5.08 PER ISSUE
This offer is **only** available via our online shop
www.magazinesdirect.com

© NASA

Asteroid collisions may be responsible for mysteriously magnetic meteorites on Earth



Reported by Rahul Rao

Rubble-pile asteroids form when asteroids collide and their shards reassemble into new asteroids. When they do, they might give the renewed asteroid a temporary magnetic field. This result might address a mystery that's baffled astronomers for years: some metallic meteorites hold traces of magnetism, as if they carry remnants of internal magnetic fields. Even if a meteorite does contain iron, it isn't expected to have a circulating dynamo like the one in Earth's inner core, which scientists think is needed to generate a magnetic field.

"I had been aware of this puzzle for some time," Zhongtian Zhang, a planetary scientist at Yale University, said. To investigate, Zhang and fellow Yale University planetary scientist David Bercovici turned to modelling asteroid collisions. When two iron-rich asteroids smashed into each other and scattered into shards, they discovered that some of those shards would coalesce into a chillier inner core that was coated by a warmer layer of molten rock. Then, if the shards were just the right size, the cold core would start stripping elements, such as sulphur, from the hot liquid. This model illustrated that the resulting heat transfer could create circulation sufficient to trigger a dynamo, and thus a magnetic field. And if such a dynamo formed, it could last for millions of years – and its traces would be detectable by astronomers long afterwards.

Weird cosmic object identified as the remains of a dead star

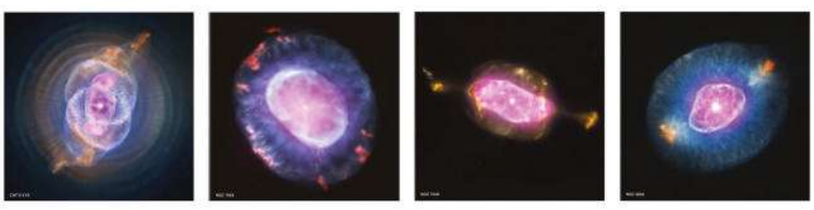
Reported by Robert Lea

A strange cosmic object that has puzzled astronomers for two decades has been revealed to be the ancient remains of a long-dead star. More specifically, new research conducted with space and ground-based telescopes has shown the object, PM 1-322, is a variable planetary nebula. Originally discovered in 2005, PM 1-322 is located around 6,800 light years from Earth. As the shells of long-dead stars, planetary nebulae such as PM 1-322 are key in understanding how elements forged by stars during their lives are spread throughout the cosmos after their deaths. Because such material becomes the building blocks for the next generation of stars and planets, planetary nebulae constitute a fossil record of our universe's evolution. But even among the most interesting planetary nebulae, with some resembling beautiful cosmic cat's eyes and butterflies, PM 1-322 stands out. That's because the new research, led by Masaryk University researcher Ernst Paunzen, indicates that PM 1-322's light output changes over long periods of time. Also, something within the object appears to be exhibiting eruption-like events.

Despite the name, planetary nebulae like PM 1-322 have nothing to do with planets. Instead they are expanding shells of gas and dust shed by stars when the stellar bodies have exhausted the hydrogen at their cores. Once that hydrogen is exhausted, the star's internal nuclear fusion process of turning the element into helium ends. This also ends the energy that supports the star from collapsing under its own gravity and triggers the rapid contraction of the core.

But as nuclear fusion still occurs in the star's outer layers, the shell of the star puffs out, turning it into what's known as a red giant. In about 5 billion years our Sun will undergo this transformation, with its outer layers swelling to the size of Mars' orbit. After this transition happens, the outer layers of the star eventually disperse, leaving behind a cooling shell of gas and dust that's illuminated by a central stellar remnant.

Analysing archival data from the Zwicky Transient Facility (ZTF) and NASA's Wide-field Infrared Survey Explorer (WISE), the astronomers also spotted a bright object associated with PM 1-322, which they designated ZTFJ201451.59+120353.4. This could be what remains of the star that created the planetary nebula. The team found that the variability of this object could indicate it's being eclipsed by a companion star. The eclipse-like event was spotted in 2022 and seemed to last around half a year. "Our most likely interpretation is that our target object involves a hot central star surrounded by gaseous and dusty discs, an extended nebula and a possible companion star," the astronomers wrote in their study. "Further observations are required to shed more light on the true nature of this enigmatic object."



An artist's depiction of the metal-rich asteroid Psyche

An array of planetary nebula as seen in X-ray and optical light

© NASA

CELESTRON SKYMASTER 20x80 WORTH £160

This brilliant binocular will provide stunning high-definition views day and night

If you're looking for a rich, high-resolution experience when watching the night sky, or even for daytime terrestrial observing, then there's no better resource to have in your arsenal than a good binocular. The Celestron SkyMaster 20x80 is of superior quality, fitted with BAK-4 prisms and multi-coated optics for exquisite views. Designed to bring the sight of distant objects into incredibly clear and sharp focus – whether you're watching the local wildlife or uncovering the members of the beautiful Pleiades star cluster – this binocular is ideal for seasoned astronomers and those just getting started in observing, while the lightweight design provides an excellent opportunity to establish a 'grab-and-go' approach to astronomy.

To be in with a chance of winning, answer this question:

What can be found in the Oort Cloud?

A: Moons **B:** Comets **C:** Stars

Competition ends on 5 October 2023

Enter via email at **space@spaceanswers.com**
Visit the website for full terms and conditions at **futureplc.com/terms-conditions**

© Celestron

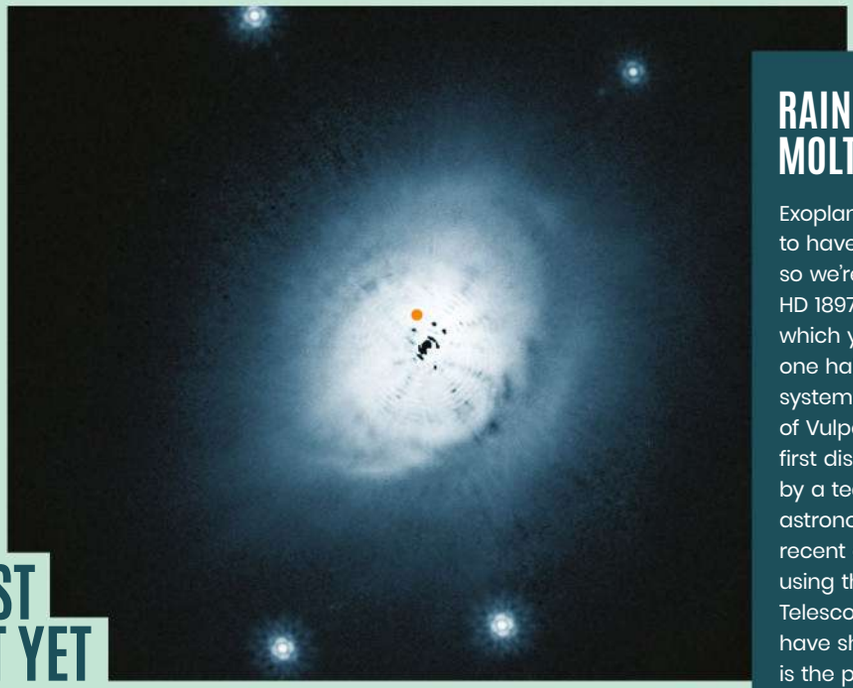
STRANGE NEW WORLDS

THE EXOTIC EXOPLANETS THAT DEFY THE LAWS OF PHYSICS

We're discovering and uncovering details about new exoplanets all the time, with some really weird worlds existing beyond the Solar System

Written by Ian Evenden

Ever since humans started discovering exoplanets – planets that orbit around stars other than the Sun – in 1992, scientists have been hunting for one that's similar to Earth. Exoplanets exist everywhere we look, and around many different types of stars. Yet none of them are Earth-like. They're too big, too hot or too bathed in radiation from their star to ever support life as we know it. The search goes on, and as new data comes in from planet-hunting missions such as the Transiting Exoplanet Survey Satellite (TESS) and ground-based telescopes such as the Very Large Telescope (VLT), there's one thing that we can be sure of: many of the exoplanets we find will be extreme.



THE BIGGEST EXOPLANET YET

Discovering the precise size of an exoplanet is a tricky thing to do. You're inferring characteristics about an object many light years away, and there's also a bit of a grey area between whether a massive object is a large planet or a small brown dwarf. HD 100546 is a star 316.4 light years from Earth that's orbited by a planet approximately 20 times the mass of Jupiter. The boundary for becoming a brown dwarf is around 19 times Jupiter's mass, putting this object well into the grey area. There are at least three other stars that are orbited by known brown dwarfs – substellar objects large enough to begin hydrogen fusion but not to sustain it. They gradually cool and darken over time, but while hot they can see a rain of molten iron on their surfaces thanks to atmospheric convection.

"HD 100546 is orbited by a planet approximately 20 times the mass of Jupiter"

RAINING DOWN MOLTEN GLASS

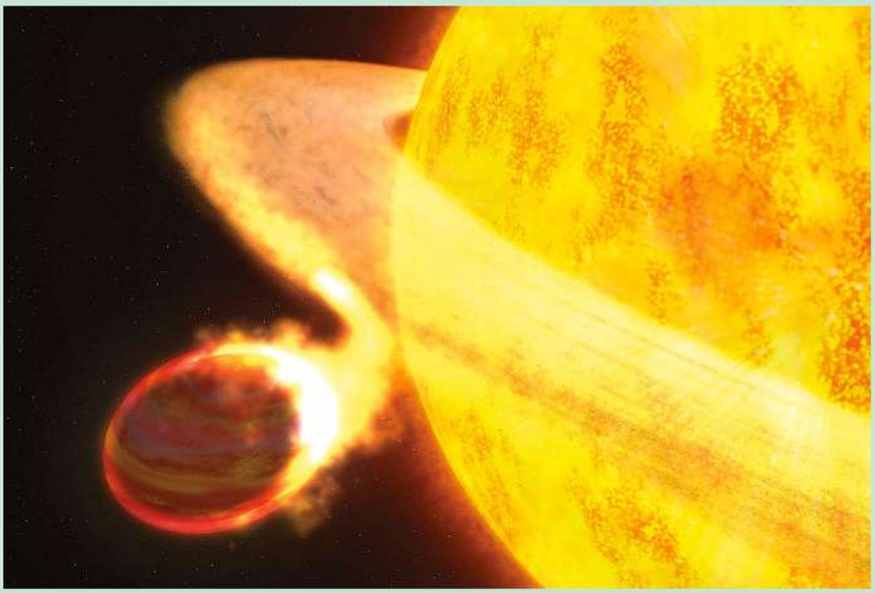
Exoplanets don't tend to have snappy names, so we're stuck with HD 189733 b for this one, which you'll find orbiting one half of a binary star system in the constellation of Vulpecula. It was first discovered in 2005 by a team of French astronomers, but more recent observations using the Spitzer Space Telescope and the VLT have shown that not only is the planet a rather pretty blue colour, its weather might be wild.

HD 189733 b is a 'hot Jupiter', a planet similar in size to the largest member of our Solar System that orbits close to its parent star, an orange dwarf, pushing up its temperature. Visitors to this planet can expect winds of up to 8,690 kilometres (5,400 miles) per hour, scorching temperatures, and a silicon-enriched atmosphere, leading to horizontal rain made of molten glass.

© ESO, ESA, NASA

TOASTY TEMPERATURES

WASP-76 b was first discovered in 2013, but an examination by the VLT in 2020 discovered that it's tidally locked. This means that, just like our Moon, one side of it constantly faces the body it orbits, in this case WASP-76, a yellow-white star in the constellation of Pisces. The planet, which is slightly less massive than Jupiter but almost twice as large, is very close to its star and orbits once every 1.8 days. Being tidally locked means one side of the planet receives an extreme amount of solar radiation, with a daytime temperature of more than 2,000 degrees Celsius (3,632 degrees Fahrenheit). Meanwhile, the nighttime side is a relatively balmy 1,000 degrees Celsius (1,832 degrees Fahrenheit). This difference in temperature means metals, vaporised by the high temperatures on the dayside, could be carried across to the night side and turn into dense clouds of aluminium, iron or magnesium.

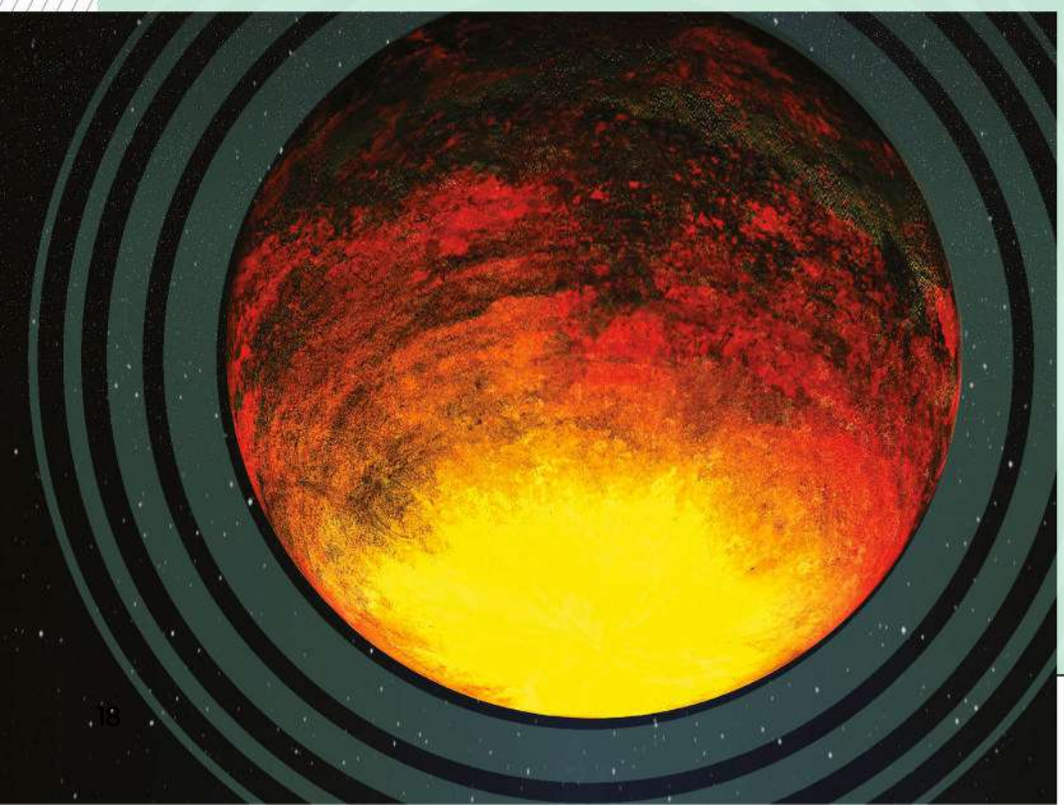


THE PLANET THAT'S LUNCH FOR ITS STAR

WASP-12 b's proximity to its star means it's sort of egg-shaped, as layers of its atmosphere are stripped away to feed the ever-hungry fusion furnace burning nearby. The Hubble Space Telescope spotted this cosmic snacking in 2010, but further research has turned up many more interesting things. The planet, which is about twice the size of Jupiter, has one of the lowest densities seen in an exoplanet yet, as this gas giant's atmosphere has been pulled out by gravitational forces to be three times larger than our Solar System's giant planet's. The planet orbits its star in just over one Earth day, but eventually WASP-12 b's orbit will decay completely and it will fall into the star, though this will not happen for an estimated 10 million years.

THE DIAMOND WORLD

There's a category of exoplanets known as 'super-Earths' that describes rocky planets less massive than gas giants but heavier than our own blue marble. 55 Cancri e is a good example. Orbiting a Sun-like star in a binary system 41 light years away, this world was the first super-Earth discovered around a main-sequence star. Situated so close to its star that each orbit takes just 17 hours, temperatures of 3,500 degrees Celsius (6,332 degrees Fahrenheit) are postulated. The planet has been inspected by two space telescopes: Hubble detected hydrogen and helium, but no water, while Spitzer's infrared view suggested a global lava ocean and volcanic activity. Strangest of all, the planet appears to be rich in carbon, which means one-third of it could be made of diamond.



A WORLD OF LAVA

Some exoplanets are named after the telescopes that discovered them, as with the Kepler series of planets. This one, which orbits a Sun-like star in the constellation of Draco over 600 light years away, has a nickname: Mustafar. If that doesn't mean anything to you, brush up on your *Star Wars* lore. The volcanic planet where Obi-Wan Kenobi duelled Anakin Skywalker has an analogue out in the universe in Kepler-10 b, the first terrestrial planet to be discovered outside our Solar System. About 1.5 times the size of Earth but three times as massive, Kepler-10 b orbits fast and close and is tidally locked, with temperatures hot enough to melt iron and possibly a rocky surface, though its high reflectivity could be due to oceans of magma.

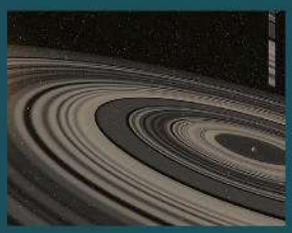
THE YEARS JUST SPEED BY

The short, 17-hour year of 55 Cancri e might seem fast, especially if you're starting to feel like time on Earth is speeding up as you get older, but it's nothing compared to the length of a year on planet PSR J1719-1438 b. It makes its home around a pulsar that flashes once every 5.8 minutes in the constellation of Serpens Cauda. Being 4,000 light years away, it's a tricky place to study in detail, and it has been theorised by one astronomer that it could be something more exotic than a star – like a lump of quark matter with the mass of Jupiter. Its planet is slightly more conventional, but it's still an extreme world. At the time of its discovery it was the densest exoplanet ever seen, being four times the size of Earth but 330 times heavier. It also orbits so closely to its star that a year on PSR J1719-1438 b lasts just 2.17 hours, and the star and planet's orbit would fit inside our Sun.

© ESA-NASA

THE DARK PLANET

Hot Jupiters are among the most commonly identified exoplanets, not only because they're large, but their tight orbits around their stars mean they whip around them at speed, giving more data for the radial velocity method of detecting them via wobbles in the stars themselves. TrES-2 b, which orbits a yellow Sun-like star that's part of a binary in Draco once every 2.5 days, is one such planet, about 1.2 times the radius and mass of Jupiter. What sets it apart from other similar worlds, however, is that it reflects less than one per cent of the light that hits it. This exceptional lack of brightness means it's darker than coal. It's theorised to be due to a lack of clouds in its atmosphere, which would reflect back more sunlight like they do on Saturn or Venus, or the presence of light-absorbing chemicals such as sodium, potassium or titanium oxide.

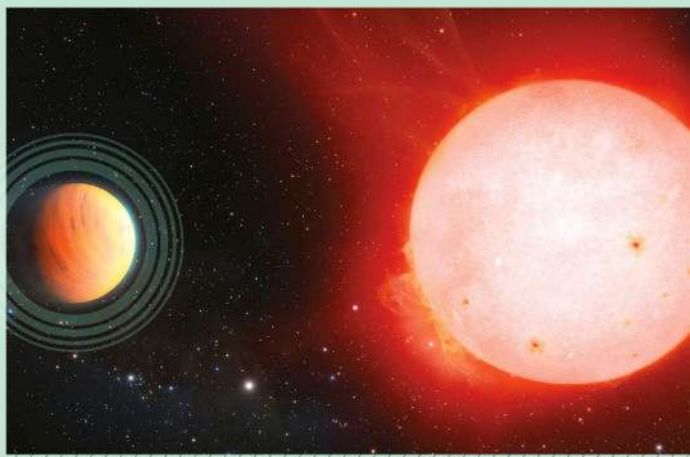


VAST RINGS

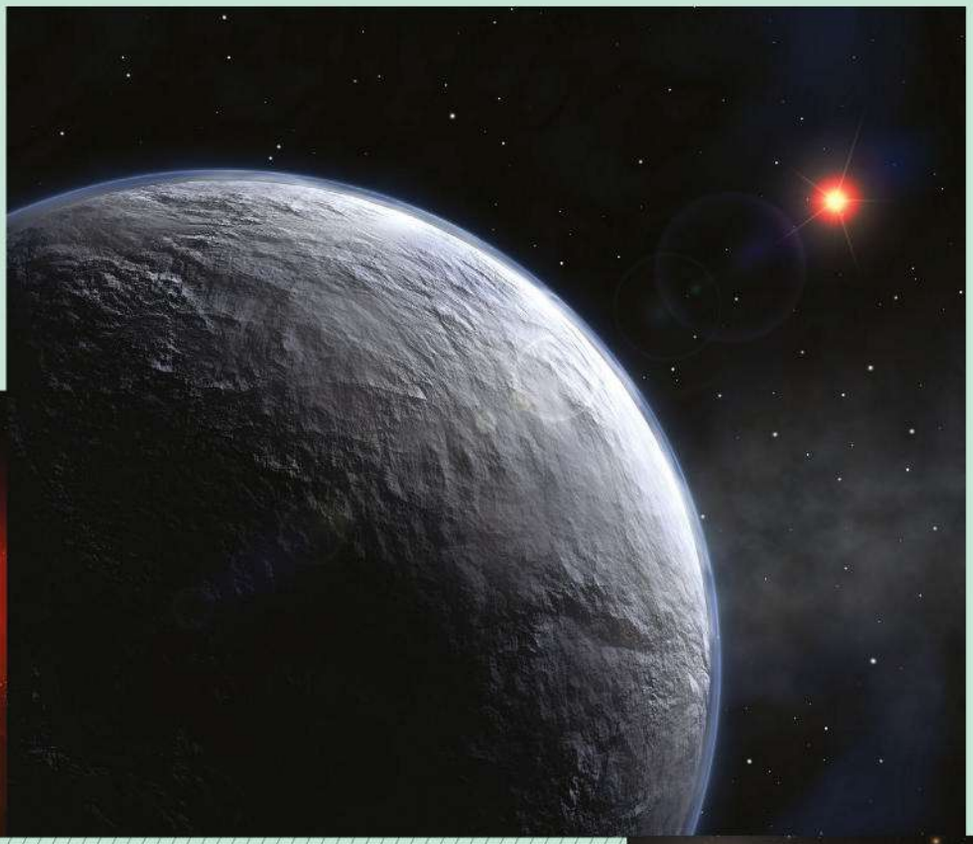
Orbiting the young star V1400 Centauri, 1SWASP J1407 b could be either a large gas giant or a brown dwarf. What's more certain is that it has an extensive ring system, approximately 200 times larger than that found around Saturn. The planet takes around a decade to orbit its star, though its path seems to be eccentric. The star's output is variable, making detection harder. With a mass between 13 and 26 Jupiter masses there's considerable uncertainty about what exactly the planet is, but gaps in its ring system suggest it's not alone. The rings themselves are thought to weigh as much as Earth, and a large gap seen as the planet and its rings transit in front of the star suggests a large moon 0.8 times the size of Earth is there too.

FLUFFIEST PLANET EVER

When we say fluffy, we don't mean like a chinchilla, but more like a marshmallow. TOI-3757 b is 580 light years away in the constellation of Auriga, orbits a cool red dwarf star and has an average density similar to that of a campfire-toasted treat. The planet is a gas giant slightly larger than Jupiter, but only a quarter of its mass. TOI-3757 b orbits its star in 3.5 days. Its solar system has less of the heavy elements you'd usually find around such a star, which means it probably formed more slowly than other planets, pulling in less gas around its rocky core and becoming less dense as a result. It also has an elliptical orbit, bringing it in very close to its star and causing its atmosphere to expand due to the intense heat.



"The planet is a gas giant slightly larger than Jupiter, but only a quarter of its mass"

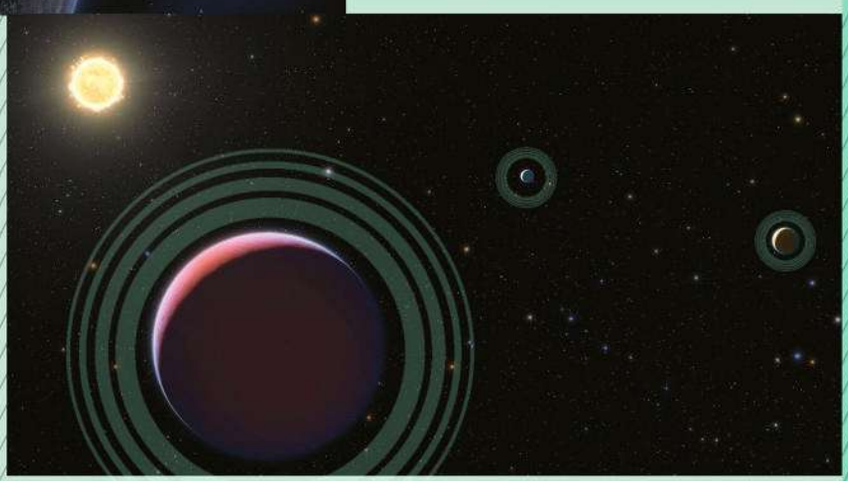


A GIANT SNOWBALL

OGLE-2005-BLG-390L b can be found 21,500 light years away in Scorpius orbiting a dim red dwarf star, and is about five times the mass of Earth. The low output of the star, and the fact the planet orbits between two and four times the distance between Earth and the Sun, which would put it beyond Mars, around the same distance as the asteroid belt, means it's significantly cooler, with a surface temperature of around -220 degrees Celsius (-364 degrees Fahrenheit). It takes about ten Earth years to complete an orbit, and it's small, with only about a quarter of the mass of Earth. Such is its chilliness that NASA has given the planet the nickname 'Hoth' after the ice planet from *Star Wars*.

BOILING HOT

We've had some hot planets on this list, with surface temperatures in the thousands, but nothing beats KELT-9 b. It takes the definition of a hot Jupiter and tears it up, hitting 4,300 degrees Celsius (7,772 degrees Fahrenheit) – hotter than some stars. And when you're this close to your home star, every day is sunny. KELT-9 b orbits a B-type star – the first such star known to have a planet – that's twice as hot as our Sun. The planet is tidally locked, orbiting so close that its year lasts just one-and-a-half Earth days. It's so hot there that molecules on the planet's surface are broken into their constituent atoms, and its atmosphere is slowly escaping, leading to a giant tail of superheated gas behind it as it zooms around its star.



A TRIO OF GIANTS

Not one exoplanet, but three. Kepler-51 is a young Sun-like star in the constellation of Cygnus that's otherwise unremarkable but for its trio of extremely low-density gas giants. These diaphanous globes are barely there at all, more like expanded polystyrene than planets as we know them. They've been named 'super puffs' – having a mass just a few times greater than Earth's but being the size of Jupiter, their material is extremely stretched out and thinly packed. They all have short years, from 45 to 130 days, and their low densities are likely a consequence of their young age – they formed as icy worlds further out in the system and have migrated inwards, so their gases are now boiling off in the warmer conditions found there. Alternatively, but much less likely, they could be smaller planets with enormous ring systems.

© NASA; NOIRLab; ESO; ESA

THE STAR THAT SPINS

Our Sun, as giant fusion reactors go, is quite placid, only troubling us occasionally with coronal mass ejections and solar flares. The three planets orbiting PSR B1257+12, however, have much more of a problem, as their star is a pulsar. The rapidly spinning neutron star at the centre of this star system, located 2,300 light years from the Sun in the constellation of Virgo, has a radius of just ten kilometres (6.2 miles) but a mass greater than that of the Sun, rotating around 160 times a second. Most of the bodies in the system have been named after undead creatures: the star is known as Lich, while two of its planets are Draugr and Poltergeist. The third planet is Phobetor, one of the sons of Somnus, personification of sleep, in Ovid's *Metamorphoses*. Only four other pulsars are known to have planets, making this system a rarity in the visible universe.

A WORLD OF ICE AND FIRE

44 light years away from us, Upsilon Andromedae b is a tidally locked planet that orbits its Sun-like star in less than five days. It's notable for the extreme difference in temperature between its day and night sides. It has a tight orbit, taking 4.6 days to complete a trip around its sun, and is a gas giant with about 1.8 times the mass of Jupiter. Infrared observations with the Spitzer Space Telescope showed that the star-facing side of the planet is around 1,500 degrees Celsius (2,732 degrees Fahrenheit) – hot enough to melt rock – while the nightside could be as cold as -20 degrees Celsius (-4 degrees Fahrenheit) and even have snow, as water vapour has been detected in the planet's atmosphere along with clouds of metal oxides.

THE WANDERER

This enormous gas giant, three times the size of Jupiter, can be found orbiting a Sun-like yellow star 102.7 light years away in the constellation of Virgo. But it's the orbit of this planet that sets it apart from many others. While we've seen exoplanets tucked in close to their stars and a few in the habitable zone or beyond, HR 5183 b is highly eccentric. Its orbital track brings it as close as 2.9 astronomical units to its star – one astronomical unit being the distance from Earth to the Sun – but also flings it as far as 42 astronomical units away over a period of around 100 years. No planetary orbits are completely circular, but the huge eccentricity in its orbit has earned the planet the nickname 'the whiplash planet'.

THE PLANET WITH TWO ATMOSPHERES

You don't need to go far to reach this extreme exoplanet, just 41 light years or so, but when you get there you might not like the smell. Gliese 1132 b is a rocky planet orbiting a small red dwarf in the constellation of Vela. It's a bit bigger than Earth and is close to its star, so a year lasts just 1.6 days. Despite receiving 19 times as much radiation from its star as Earth does, it's managed to hold onto its atmosphere, with a thick layer of methane and hydrogen cyanide pumped out of volcanoes. These are caused as the planet flexes as it orbits its star, pushing gases up to the surface. The planet has a surface temperature hotter than Venus, and the volcanic gases are replacing the original atmosphere of hydrogen and helium that was left over from the planet's formation.

THE PLANET IN ANOTHER GALAXY

M51-ULS-1 b is an exoplanet candidate in the Whirlpool Galaxy, a whopping 28 million light years away. Given the distance, we know a surprising amount about it. NASA's Chandra X-Ray Observatory was watching the X-ray emissions of a binary system comprising one large star and an object that may be a neutron star or small black hole when it spotted the telltale dip in intensity that occurs when an orbiting body passes between the emitter and observer. From this, scientists were able to work out that it's probably a planet slightly smaller than Saturn and orbits at a distance similar to Saturn or Uranus from our Sun.

"Scientists were able to work out that it's probably a planet slightly smaller than Saturn"

THE ONE MOST LIKE EARTH

Teegarden b ticks a lot of the right boxes as far as potential habitability is concerned. In the Earth Similarity Index, a way of classifying exoplanets that takes into account size, density, gravity, temperature and other characteristics to provide a measure of how similar a planet is to Earth, this distant world, 12.5 light years away in Aries, sits at the top. That's no guarantee of habitability though. Teegarden's Star is a red dwarf one-tenth the size of our Sun that's only just large enough to become a star and not a brown dwarf. This lack of light output means its habitable zone is much closer than that of our Sun, and Teegarden b has a year that lasts just five Earth days. However, it's approximately Earth-sized, likely to be rocky and has a 60 per cent chance of being home to liquid water, but according to astronomers only a three per cent chance of having an atmosphere.

© NASA; ESA; Source: Wikipedia Commons ; Arndt Stelter

SPACE FACTORIES

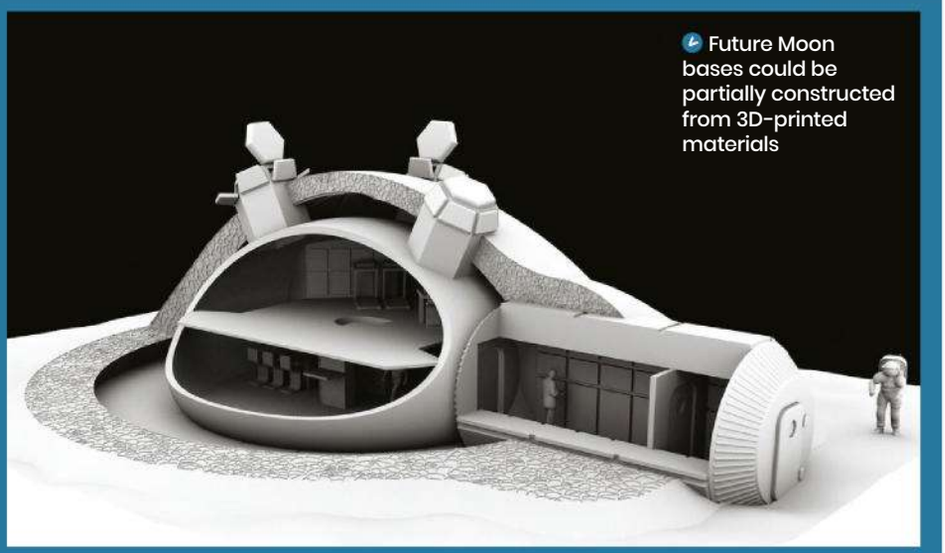
The prime challenge of living in space – besides the inherent danger – is figuring out how to bring enough with you to survive. Equipment, oxygen, food and water all need to be hauled there, but could there be an alternative solution?

Every single kilogram that must be hauled into space for human crew requirements represents one kilogram less that can be used for science experiments. More capable rockets is one solution to this problem. But what about actually making the components and food you need on site? The idea isn't as far-fetched as it sounds. The European Space Agency (ESA), NASA and others are testing out 3D printing as a way to manufacture structures, rocket parts and even pizza.

Looking really far ahead, the ESA suggested that 3D printing could reduce the cost and complication of future lunar bases. "3D printing offers a potential means of facilitating lunar settlement with reduced logistics from Earth," says Scott Hovland of the ESA's human spaceflight team.

The first step is to find a structure that works. Astronauts could haul an inflatable dome with them, perhaps, but they would still require a heavy shield to protect against radiation and micrometeoroids. A proposal from Foster + Partners suggests a shield with a structure similar to what you would see in a bird's bones: lightweight, hollow cavities, plus strength to hold itself up. A 3D

< Foster + Partners created this 1.5-tonne building block using 3D printing



Future Moon bases could be partially constructed from 3D-printed materials

1 Using local resources

Any manufacturing process on the Moon will likely make use of local resources – such as regolith, or lunar soil – to reduce the cost.

2 Helping human exploration

3D printing is expected to make it easier for human missions to occur on the Moon and other places outside Earth.

3 Next-generation lunar base

This base would be a combination of an inflatable structure as well as a 3D-printed shield to prevent micrometeoroids and radiation from penetrating it.

4 Machine making

It's possible that machines could be partially or completely manufactured from 3D-printing processes, although it's too early to say for sure.

printer would build up the layers gradually, but right now the technology is a little slow: perhaps two metres per hour (6.6 feet per hour). A next-generation printer proposed by the UK's Monolite could attain speeds of 3.5 metres per hour (11.5 feet per hour), or enough to put together a reasonable-sized building in a week.

Structures are one issue, but feeding astronauts is a more pressing one. For those of us who know how full the fridge gets after only a few shopping trips, imagine how much would need to be hauled to survive months or years on the road. In 2013 NASA gave a Phase 1 contract to Texan company Systems and Materials Research Consultancy to explore the possibility of making food in space. One of NASA's main aims is to "enable nutrient stability and provide a variety of foods from shelf-stable ingredients," the agency stated.

The food definitely has applications for space travel, but with NASA being an agency that advertises spin-offs, you can guarantee it's also thinking of Earthly applications for the technology. If food could be manufactured reliably and safely, imagine the difference it could make in handing out assistance in an area devastated by a hurricane, flood or other natural disaster. Countries that are also having regular problems feeding the populace through their own agriculture could supplement their own efforts with 3D-printed food. It's perhaps a little audacious to hope it could eliminate world hunger, but manufacturing food in this way would be a start towards it.

But what about making rocket components themselves out of 3D-printed technology? It could reduce the cost of space missions because it could lead to on-site printing, making it easier to manufacture. No need to order out for special parts. NASA and Aerojet Rocketdyne previously tested a rocket engine injector created through 3D printing. Happily, the tests went just fine: the agency and contractor put the component through a series of firings and were pleased with the results. The injector can be made in a third of the time – four months instead of over a year with traditional processes – and costs 70 per cent less.

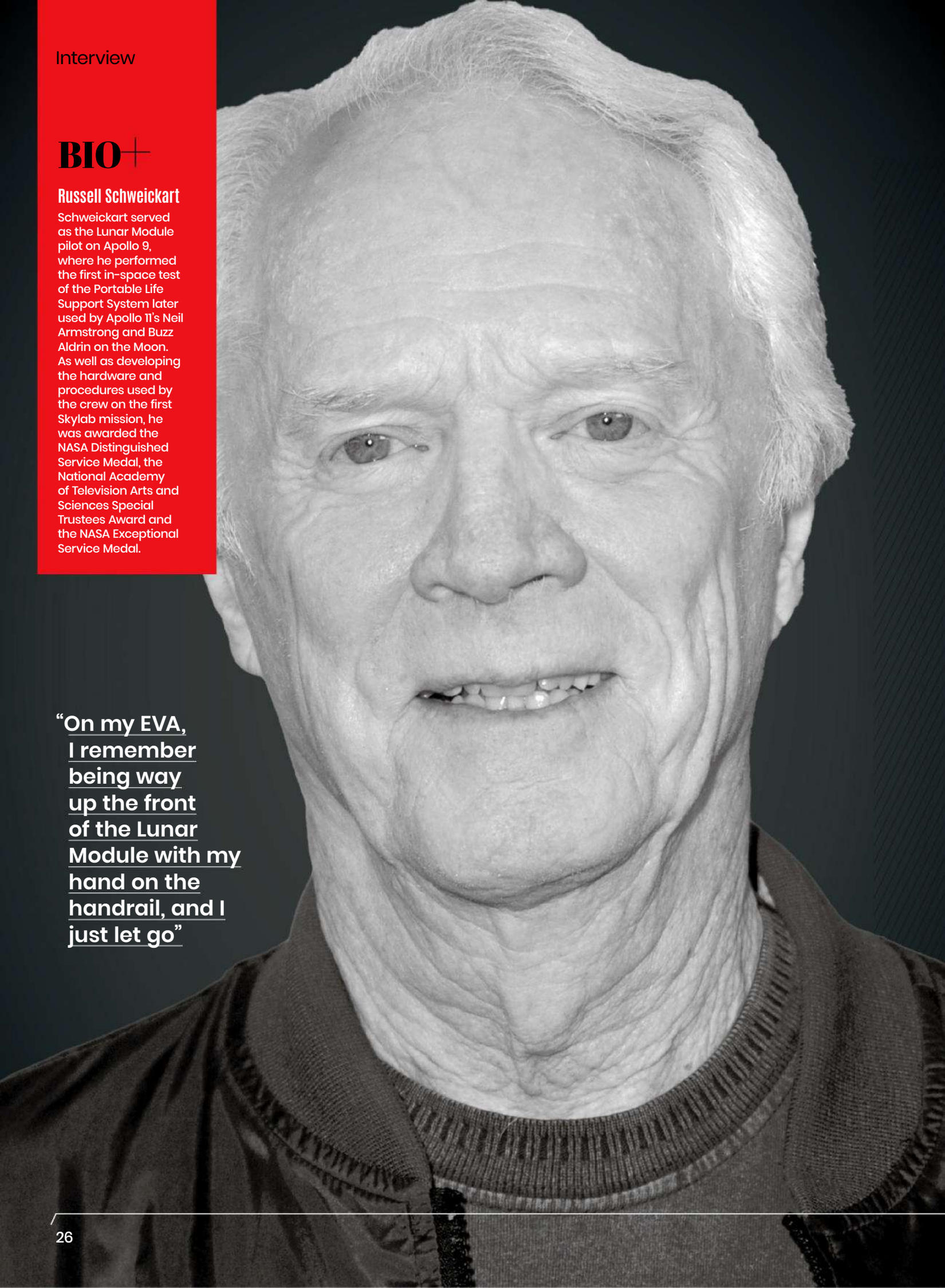
While still in its infancy, 3D printing provides a possible route to solving a lot of problems in space exploration, such as manufacturing things, and also hauling food and other items on long-distance voyages. The next job is making sure there's a technician on hand to fix the printer off-planet if it breaks down from overuse.

© ESA

BIO+

Russell Schweickart

Schweickart served as the Lunar Module pilot on Apollo 9, where he performed the first in-space test of the Portable Life Support System later used by Apollo 11's Neil Armstrong and Buzz Aldrin on the Moon. As well as developing the hardware and procedures used by the crew on the first Skylab mission, he was awarded the NASA Distinguished Service Medal, the National Academy of Television Arts and Sciences Special Trustees Award and the NASA Exceptional Service Medal.



"On my EVA, I remember being way up the front of the Lunar Module with my hand on the handrail, and I just let go"

Apollo 9's Rusty Schweickart

"Going outside the spacecraft is very special"

The retired NASA astronaut tells **All About Space** how a jammed camera during a spacewalk changed his life

Interviewed by Rafael Maceira Garcia

If NASA had stuck with its original rosters, the crew of Apollo 9 should have flown on Apollo 8, circling the Moon during Christmas 1968. How did you take the news that you weren't going to fly to the Moon after so much hard training?
Those were very complicated times, and the mission shifted all over. We were actually the backup crew for the first Apollo missions, including Apollo 7, but we were also going to pick up the Lunar Module and be the first to fly it. Then we were shifted off the backup crew and Wally Schirra's team took our places for the first Apollo mission, with Gus Grissom, Roger Chaffee and Ed White the appointed first-choice crew. We moved into a totally different mission, but we were going to fly the Lunar Module. Then that didn't work and Frank Borman proposed moving his flight.

Did you ever have the feeling of having lost the chance of going to the Moon?
Not then, but after we flew on Apollo 9 and tested the Lunar Module in Earth orbit, the next rotation would have been to go from Apollo 9 to being backup for Apollo 12 and then a member of the prime crew on Apollo 15, which Dave Scott did. But things changed because I had gotten sick on Apollo 9.

I had motion sickness, and as the first person not to get sick, but the first person to acknowledge it – that's an important difference – there was a big question as to whether people getting sick might actually make going to the Moon unsafe and dangerous for people. We had to learn something about that, and I volunteered to be the guinea pig to test motion sickness so that we came to understand what was going on there and how we could overcome it and so on... so that took me out of the normal rotation. That's the way that happened.

You lifted off as the pilot of the Lunar Module with the first complete Apollo spacecraft on 3 March 1969. What moments or lessons would you point out from that experience?
I mean, the primary lesson from our experience on Apollo 9 was that everything worked well. We'd had a lot

Inside the Apollo Lunar Module mission simulator at Kennedy Space Center, Florida, during Apollo 9 mission training

© Getty: NASA

Russell "Rusty" Schweickart was selected in 1963 for NASA's third astronaut group

The Apollo program was debatably the most successful human spaceflight program carried out by NASA

of problems in Gemini doing extravehicular activities (EVAs) with a suit, and they were largely unsuccessful, but we had the brand-new suit. I had to go on the EVA, the first experience of going outside, and fortunately, nothing really dangerous happened. We also had the backpack that was going to allow us to run around on the Moon. So that was a very important test that we did in Apollo 9.

Did you have to deal with the motion sickness too?
Yes, but that was over by the time we actually did the EVA. We had to postpone the EVA because I had motion sickness the day before, and you don't get in a suit and go outside in space if you're going to have motion sickness, because that will kill you. I mean, if you vomit in the suit you will die. It's very dangerous.

You have the honour of being the astronaut that performed the first Apollo spacewalk, testing the new spacesuit's integral life-support systems. How do you recall your feelings before and during such a historic time?
Going outside is always a special time for any astronaut, no matter how you do it. Whether you're the tenth or the thousand person, going outside the spacecraft is always a very special experience because you're really out there, you're no longer looking through a window. Even if you looked around in your Apollo suit you didn't see the edge of anything, so it's as if you're naked in space. And if you're not moving around you don't feel the suit, as you're floating inside it, so the feeling is very much of just being out there all by yourself. It's always a special time. Then, on Apollo 9, I recognised that we'd had problems before in the suit, and we didn't know what to expect from the new Apollo spacesuit. We also never flew with a totally self-contained backpack – I only had a tether to the spacecraft. There was no umbilical cord, so in other words, I had no services coming through that tether. Everything was on my back and in the suit. I was an independent spacecraft really, linked by a string, and it all worked beautifully.

As a fighter pilot and an astronaut you're trained to handle risk – were there any risky moments?
We really didn't have any risky moments. Everything worked well. There were a couple of surprises when we first undocked the two spacecraft. It gets a little bit technical, but there were some very small little latches that had to release, and in the simulator on the ground, when we did the procedure everything worked well. David Scott, in the Command Module, threw the switch and the two spacecraft separated. Springs pushed us apart and the spacecraft moved away, but when Dave pushed the switch and let it go in the

© NASA

actual situation, the probe hadn't fully extended. He just hit the switch and let it go, which is what we did in the simulator on the ground, but when it reached the end of its travel pushing the Lunar Module away, those little latches, as soon as he let go, went back out, and so we went 'clunk', and stopped. We kind of looked at each other and wondered, 'what was that?' James McDivitt and I said we should probably redock and figure out what happened. We wanted to let the ground team work through it, figure out what happened and then do it again. At about that time, Dave looked up and saw that we weren't separated and he just hit the switch again. As we started to drift off, we looked at each other and said: "Well, too late now! We'll find out when we come back from the rendezvous in eight hours if anything is wrong."

What do you treasure most from your mission?
The EVA. Being outside the spacecraft and having five minutes to myself when the movie camera that was documenting my EVA failed. McDivitt said: "Okay Dave, you've got five minutes to try and fix the movie camera. Rusty, just stay there." Well, that was great! I mean, I had five minutes to just stay there and look at where I was. That was pretty special.

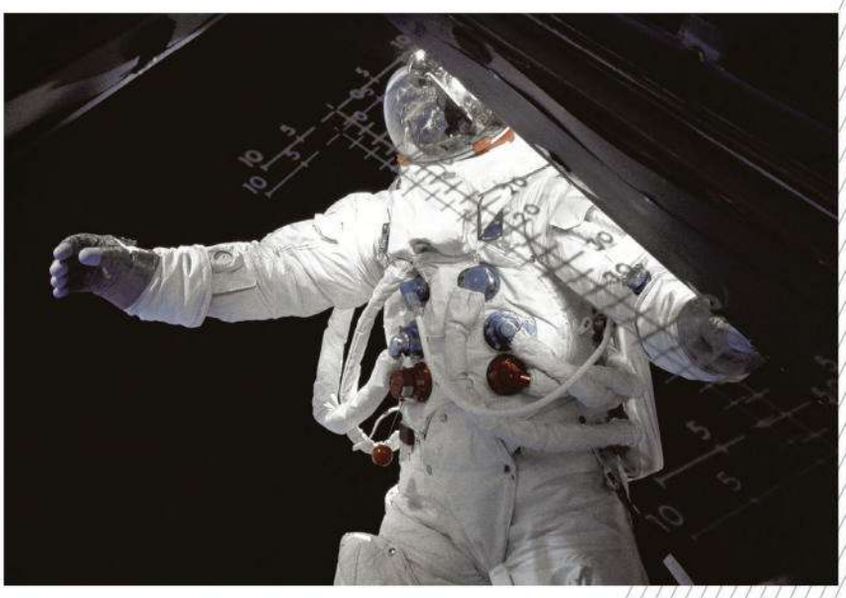
Did the mission change you in any way?
Yeah, because you know, during those five minutes... I remember being way up the front of the Lunar Module with my hand on the handrail, and I just let go. With one hand I swung myself around and looked at Earth; the Command Module was also in that direction, but mainly I could see Earth, the black sky and the black universe above it. I just said to myself: "This is my time to be a human, not to be an astronaut. I'm not going to think about what's next on the checklist. My job is to be a sponge, to just let this come in through the spacesuit and into me as a human being." And that happened. Many years afterward, I was still processing it. A lot of questions came to me: How did I get here? And I don't mean by a Saturn V. How do I happen to be here? I was a farm kid from New Jersey. What's happening? What does this mean? Why am I here? What are the implications of this? What is my responsibility? All of those things just came flooding in, and those were things that I processed for several years afterwards, before I really talked about that experience in that sense.

What do you think is the legacy of Apollo 9?
Apollo 9 was the engineering test flight. We would basically test everything. Everybody said it was the engineer's flight, because everything that had to work in order to make a successful lunar landing was tested. Well, not everything, because we didn't test any of the actual landing radar, for example, because we didn't have the Moon there. But 90 per cent of what had to work, we tested on our flight. In some cases we went beyond the normal test to make it extra difficult. It was a very important flight in terms of proving that we really were ready to go out to the Moon and land.

Are you still involved with the space program in any way?
I'm not directly linked to the space program in terms of NASA, for example, but the last few years of my life have been spent working on what we refer to as planetary defence: protecting Earth from asteroid impacts. That's what I really am very proud of. I'm as proud of that as I am of having flown on Apollo. Anyone could have flown on Apollo, but that work on the B612 Foundation and the Association of Space Explorers, both of which I founded, and the work that we've done in enabling humanity to protect Earth, and the life on it, from asteroid impacts will be a very important legacy.

Do you think a trip to Mars is as challenging and risky as the Apollo program?
I think there's no question – it's far more risky. We know one of the biggest problems in going to Mars is the radiation environment. You are not only going into space for a long time, you're outside of Earth orbit where you're protected by the radiation belts. That happens when you're in the International Space Station, but when you get out into deep space you are exposed to heavy particles. We don't really have a good way to protect people from radiation damage. A small group of people going for that long would also experience psychological challenges. The experience of Antarctica, the South Pole, over winter is small compared with a group of people going to Mars for three years. Those things are challenges that we understand, and didn't exist in going for a week or something to the surface of the Moon with three people. Going to Mars is going to be a much bigger challenge, and it's not clear to me how soon we're going to be able to do that.

Would you go if you had the chance?
I don't think so... Perhaps if my family disowned me, I would think about it, but now I think it's for younger people to do.



Schweickart performing an EVA, photographed by fellow astronaut James McDivitt from inside

FOCUS ON

A 'METEORITE' THAT STRUCK A FRENCH WOMAN WAS JUST A REGULAR EARTH ROCK

Astronomers don't think the rock came from space

Reported by Robert Lea

In a viral story, a French woman describes how she was injured when she was struck by a rock from space. But experts suggest that all is not what it seems. The woman, a resident of Schirmeck in the French department of Bas-Rhin, said that she was sitting on her terrace on 6 July when she heard a shock on the roof. A pebble then fell off the roof and hit her at rib level. "I heard a big 'poom' coming from the roof next to us. In the second that followed, I felt a shock in the ribs. I thought it was an animal, a bat," the woman said. "We thought it was a piece of cement, the one we apply to the ridge tiles, but it didn't have the colour."

An image of the suspected space rock showed it was black with sharp edges. But l'Observatoire de Paris astronomer Jérémie Vaubaillon explained that the rock is definitely not from space. "The pictures clearly show this is not a meteorite. These rocks have way too many angles to be meteorites. Remember that during its flight in the atmosphere, the initial rock melts because of the surrounding superhot plasma," Vaubaillon said. "Picture an ice cube melting – there are no angular pieces left. The same is happening for a meteorite as it passes through the atmosphere."

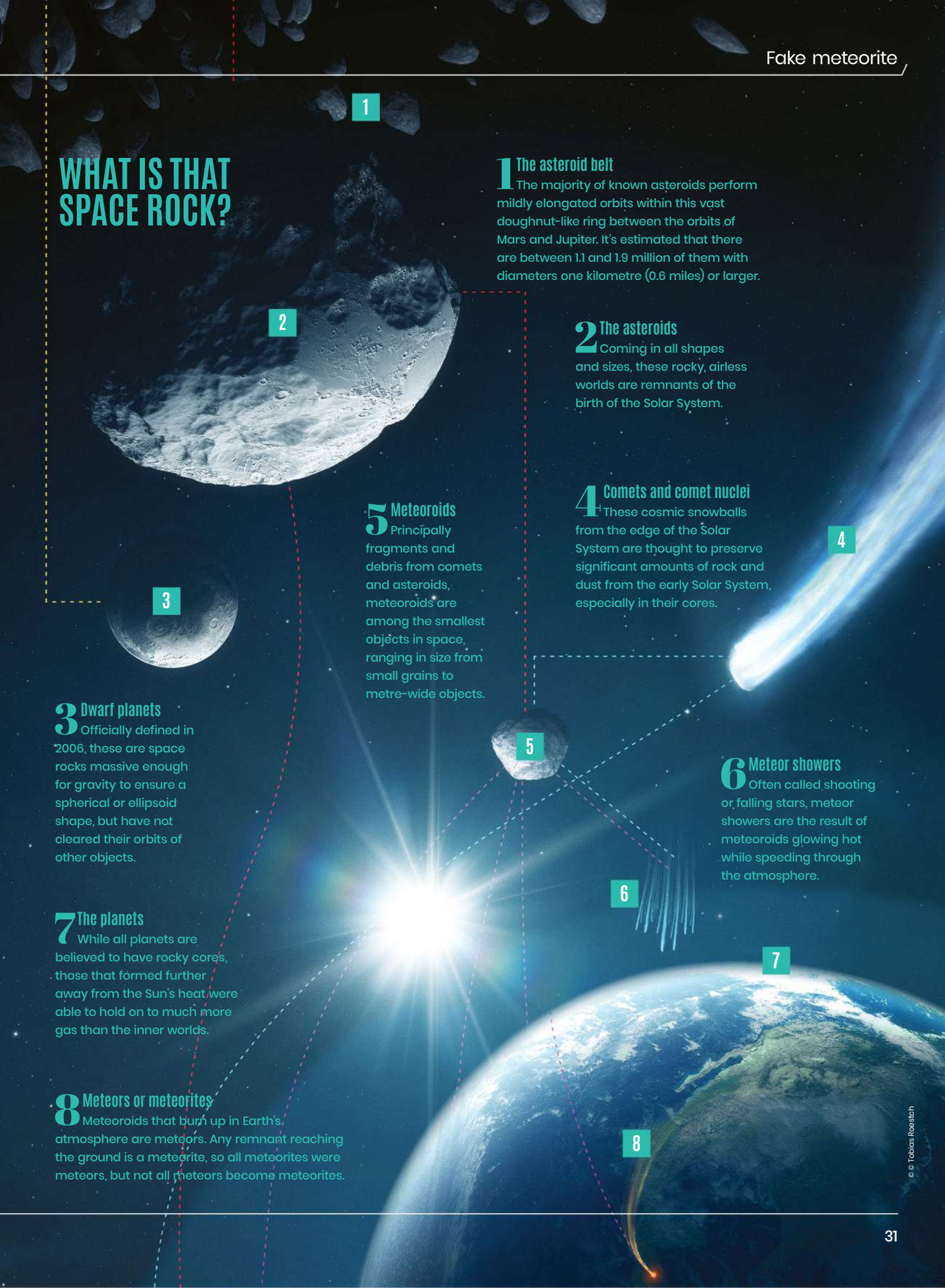
The rock also has a 'bubbled' and irregular surface. This feature is common with volcanic rocks: bubbles of lava are frozen as the molten rock quickly cools. Space rocks that pass through Earth's atmosphere, on the other hand, tend to have smooth surfaces due to the heat they experience and the melting it causes, as Vaubaillon noted.

Few people doubt that something struck the French woman on 6 July. But Vaubaillon isn't the only expert expressing scepticism about the offending rock supposedly coming from space. François Colas, an astronomer with the Fireball Recovery and InterPlanetary Observation Network (FRIPON) sky surveillance network, explained that when a meteorite falls from the sky, it tends to arrive at the surface at approximately 300 kilometres (186 miles) per hour after being slowed by its passage through the atmosphere. If the 6 July rock were a meteorite, it should have damaged the roof when it hit. But that didn't happen here, Colas said. Additionally, FRIPON monitors the sky over France for flashes of light caused by meteors, but none were detected in the area on 6 July.

If this was a space rock, the object was also missed by other skywatchers. "Such an object reaches magnitude -15.0 – it does not go unnoticed. In this season, there are also many amateur astronomers who observe. They would have reported such an event," Colas explained. The odds don't favour an extraterrestrial origin for the rock, either. Vaubaillon explained how incredibly unlikely it would be to be hit by a meteorite falling to Earth. "Meteorite falls are rare; most of the meteorite material is melted during atmospheric entry," the astronomer said. "In order to survive the entry and make it to the ground, the rock has to be both slow and large, above 1.6 feet [0.5 metres] in diameter, and large objects are rare."

In addition, Earth is an extremely big target for space rocks, and around 71 per cent of its surface is ocean. "The surface of the Earth is very wide compared to the size of a human," Vaubaillon said. "Two-thirds of meteorite falls end up in the ocean, and most of the remaining ones end up in fields, forests and deserts." Vaubaillon calculates that the chances of a person being hit by a meteorite are about 1 in 100 trillion. And that tiny probability should be quite a relief. The astronomer also explained what it would be like to be directly struck by a meteorite. "It would hurt!" he said. "It depends on the rock size, but they fall from high altitude and their speed stabilises at around 190 miles [306 kilometres] per hour. Imagine you are hit by a rock while driving at such speed. This would hurt you a lot."

WHAT IS THAT SPACE ROCK?



1 The asteroid belt
The majority of known asteroids perform mildly elongated orbits within this vast doughnut-like ring between the orbits of Mars and Jupiter. It's estimated that there are between 1.1 and 1.9 million of them with diameters one kilometre (0.6 miles) or larger.

2 The asteroids
Coming in all shapes and sizes, these rocky, airless worlds are remnants of the birth of the Solar System.

3 Dwarf planets
Officially defined in 2006, these are space rocks massive enough for gravity to ensure a spherical or ellipsoid shape, but have not cleared their orbits of other objects.

4 Comets and comet nuclei
These cosmic snowballs from the edge of the Solar System are thought to preserve significant amounts of rock and dust from the early Solar System, especially in their cores.

5 Meteoroids
Principally fragments and debris from comets and asteroids, meteoroids are among the smallest objects in space, ranging in size from small grains to metre-wide objects.

6 Meteor showers
Often called shooting or falling stars, meteor showers are the result of meteoroids glowing hot while speeding through the atmosphere.

7 The planets
While all planets are believed to have rocky cores, those that formed further away from the Sun's heat were able to hold on to much more gas than the inner worlds.

8 Meteors or meteorites
Meteoroids that burn up in Earth's atmosphere are meteors. Any remnant reaching the ground is a meteorite, so all meteorites were meteors, but not all meteors become meteorites.

© Tobias Roetsch

SCI-FI NIGHT SKY

Look out into the universe and you'll recognise some of its members have played a part in the works of science fiction

Written by Stuart Atkinson

It's no surprise that many of today's astronomers are also fans of science fiction. Indeed, it's how many of us became interested in 'space' in the first place. As children we watched Captain Kirk whizzing from planet to planet on *Star Trek*; hid behind sofas watching the Doctor battling the Daleks; visited the cinema to watch the *Star Wars* films, *Close Encounters of the Third Kind* and *E.T. the Extra-Terrestrial* and read science-fiction novels by Stephen Baxter, Kim Stanley Robinson and others.

It's true that, for many people, the imaginary science-fiction worlds visited by the USS Enterprise and the TARDIS are as fascinating, beautiful and real as anywhere visited by Viking, Voyager and Cassini. And on a clear night it's possible to visit many of these imaginary places with a telescope. Although the planets themselves are made up and don't actually exist, we can look up into the night sky and see the stars they were placed in orbit around by screenwriters, directors and authors over the years.

THE INTERNATIONAL SPACE STATION

Some time in the next couple of years, film star Tom Cruise will fly up to the International Space Station (ISS) to shoot sequences there. But the ISS has already featured in many science-fiction films, including *Gravity*, where disaster-prone astronaut Sandra Bullock borrows a Russian Soyuz capsule; *Life*, where an alien life form from Mars goes on a killing spree, and *The Day After Tomorrow*, where astronauts look down helplessly at Earth as it freezes beneath them. But Cruise won't be the first actor to go to the ISS. In October 2021 Russian actress Yulia Peresild spent 12 days up there filming zero-gravity sequences for the film *The Challenge*. From Earth the ISS looks like a bright 'star' that crosses the sky from west to east. If you want to see it in the sky this month you can use various websites and apps to calculate if and when it will be visible from your location.

© Getty

THE MOON

The Moon features in countless science-fiction films, including *2001: A Space Odyssey*, *Moon* and the 1950 pre-Apollo classic *Destination Moon*. Fans of British science-fiction have fond memories of watching the nuke-snouted interceptor spaceships of SHADO blasting UFOs out of the Moon's inky-black sky in *UFO* and of seeing the Moon itself blasted out of Earth orbit in *Space: 1999*. Our lunar companion was also the setting for Arthur C. Clarke's beloved short story *The Sentinel*, which inspired *2001*.

Many of the locations visited in these science-fiction works are real and can be seen on the Moon using a binocular or a telescope. *2001*'s craters Tycho and Clavius can be found down near the 'bottom' of the Moon's face.

MARS

As well as being the home planet of the aliens who invaded Earth in *The War of the Worlds*, only to be killed by the common cold, Mars has featured in other classic works of science fiction. Edgar Rice Burroughs' John Carter of Mars books have thrilled readers for generations, and more recently cinema-goers cheered as disco music-hating Mark Watney escaped from Mars in *The Martian*. Readers of hard science fiction love Kim Stanley Robinson's *Mars* trilogy with the same passion J. R. R. Tolkien's readers feel for his books, and Stephen Baxter's alternative history novel *Voyage* paints a realistic but sad picture of a crewed mission to Mars in 1986.

Unfortunately, the real Mars will be hard to see in the sky this month. But at the end of next year it will be an impressive sight in the sky, a strikingly bright-orange star close to the Beehive Cluster.

ASTEROIDS

Asteroids are everywhere in science fiction. *Armageddon* follows Bruce Willis and his rag-tag crew of oil workers on their mission to save Earth from an asteroid impact. In his novel *Seveneves*, writer Neal Stephenson describes how a small number of people survive Earth's destruction by taking shelter on board the ISS. But in too many films and TV series to count, space pilots duck and dodge through belts of thousands of tumbling asteroids, packed so close together that they're constantly colliding. The truth is that asteroids are actually so far apart that if you stood on one your nearest neighbour would be just a dot in the sky.

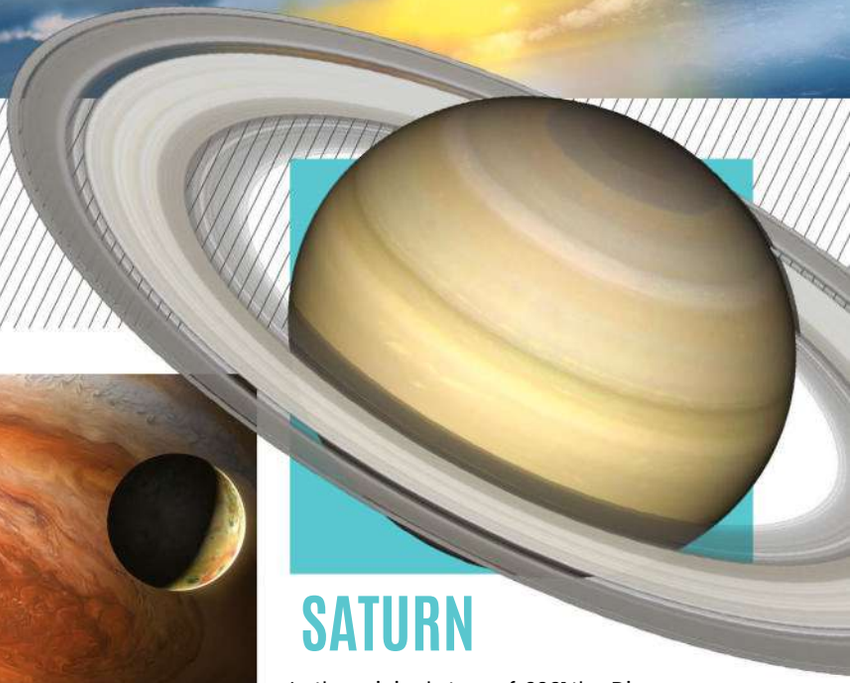
This month the asteroid Vesta is very well-placed for observation. You'll find it looking like a tiny star beneath and between the stars Chi^{1} and Chi^{2} Orionis, but at eighth magnitude you'll need a binocular to see it.

PLUTO

Although Kim Stanley Robinson is best known for his epic Martian tales, he also set a novel on Pluto. *Icehenge* was published in 1984, almost 20 years before the New Horizons probe flew past Pluto and showed us its vast plain of ice in the shape of a heart and the colour of salted caramel ice cream. If you want to see Pluto in the sky you'll definitely need a telescope to track it down among the many stars of Sagittarius, looking like a speck of dust surrounded by other specks.

JUPITER

Jupiter featured in *2001* and its sequel *2010: The Year We Make Contact*. In 1981, Sean Connery travelled to Jupiter's moon Io to be the marshall of a corrupt mining colony in the underrated *Outland*. If you want to see Jupiter in the sky this month you'll find it looking like a bright blue-white star to the right of the beautiful Pleiades star cluster. A telescope reveals its famous Great Red Spot and caramel-coloured cloud belts, and binoculars will show its four largest Galilean moons, including Io.



SATURN

In the original story of *2001* the Discovery was sent to Saturn, not Jupiter, to track down the source of the alien signal activated by the mysterious lunar monolith. In the classic environmental science-fiction film *Silent Running*, a lone astronaut and his robot friends fly the huge Valley Forge spacecraft – and Earth's last remaining forests – through Saturn's rings. In Stephen Baxter's novel *Titan*, a team of scientists travel to that planet-sized moon and discover life there, just as Earth is destroyed by an asteroid impact.

Saturn is visible this month as a golden-hued star in the evening sky, over to the right of Jupiter. If you want to see its beautiful rings you'll need a telescope, but binoculars will show you Titan as a star close to Saturn itself.

© Getty

NEPTUNE

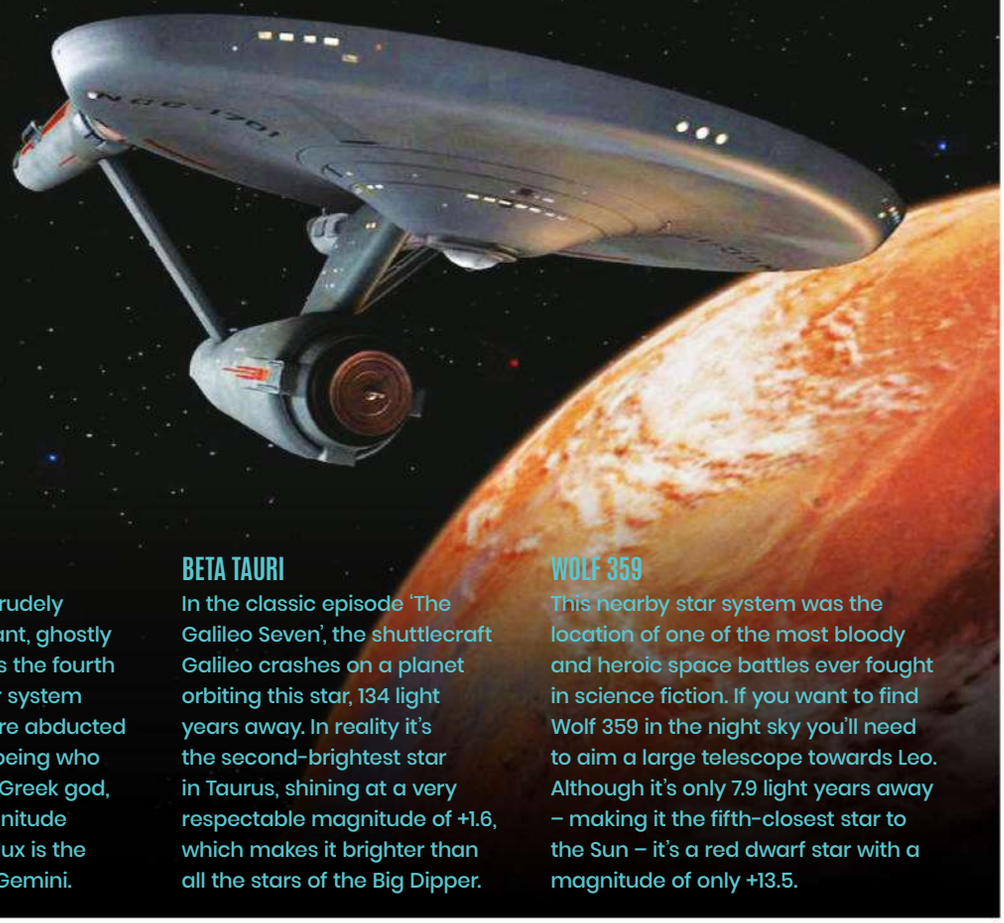
Neptune has been rather overlooked in science fiction. In *Ad Astra*, melancholy astronaut Brad Pitt travels to Neptune to find his missing father and prevent the destruction of the Solar System. Ridiculed by many, it's quite scientifically accurate... in places. The Moon buggy chase scene is excellent, and the bloody-muzzled space monkeys are genuinely scary. If you want to see this turquoise-tinted world this month, you'll need to aim a binocular or a telescope towards the faint stars of Pisces.

COMETS

Science-fiction loves smacking comets into Earth and wiping out civilisation. In *Deep Impact* – which came out around the same time as *Armageddon* but was a lot more gloomy and serious – brave astronauts sacrifice themselves by flying their crippled spacecraft into an Earthbound comet. More recently, the movie *Don't Look Up* featured a doomsday comet which survived our attempts to deflect it. Probably the best science-fiction novel set on a comet is *Heart of the Comet*, written by David Brin and Gregory Benford, which describes a doomed crewed mission to Halley's Comet in 2061. If you want to see a real comet in the sky this month you'll have to look towards the constellation of Auriga. Around mid-month Comet 103P/Hartley will be close to the Kids, a triangle-shaped asterism of three stars close to bright Capella, looking like a smudgy, out-of-focus star in a binocular.

THE WORLDS OF STAR TREK

Without doubt the science-fiction franchise which has visited the most alien planets is *Star Trek*. Over the decades the USS Enterprise and a fleet of other beautiful Federation starships have explored the galaxy, causing all kinds of trouble on countless strange new worlds.



40 ERIDANI

This magnitude +3.7 star in the constellation of Eridanus is just over 16 light years away and is orbited by the planet Vulcan, the homeworld of Spock, the Enterprise's science officer.

POLLUX

The Enterprise is rudely grabbed by a giant, ghostly hand as it passes the fourth planet in the star system before its crew are abducted by a giant alien being who claims to be the Greek god, Apollo. First-magnitude orange giant Pollux is the brightest star in Gemini.

BETA TAURI

In the classic episode 'The Galileo Seven', the shuttlecraft Galileo crashes on a planet orbiting this star, 134 light years away. In reality it's the second-brightest star in Taurus, shining at a very respectable magnitude of +1.6, which makes it brighter than all the stars of the Big Dipper.

WOLF 359

This nearby star system was the location of one of the most bloody and heroic space battles ever fought in science fiction. If you want to find Wolf 359 in the night sky you'll need to aim a large telescope towards Leo. Although it's only 7.9 light years away – making it the fifth-closest star to the Sun – it's a red dwarf star with a magnitude of only +13.5.

THE WORLDS OF BABYLON 5

Fans of this hugely popular TV series can see many of its locations in the night sky.

EPSILON ERIDANI

The sprawling space station Babylon 5 – Earth's last hope for peace – orbits the third planet in this star system. It was from here that the Earth Alliance and its allies fought against the Shadows and other alien threats. You'll find the real star in the southern constellation of Eridanus. It's a magnitude +3.7 Sun-like star, just over ten light years from Earth, making it the third-closest star system visible to the naked eye.

CHI DRACONIS

Babylon 5's enigmatic Minbari live on Minbar, a fictional planet in this system. Chi Draconis itself is a magnitude +3.5 star in Draco, 26 light years away from us.

CANOPUS

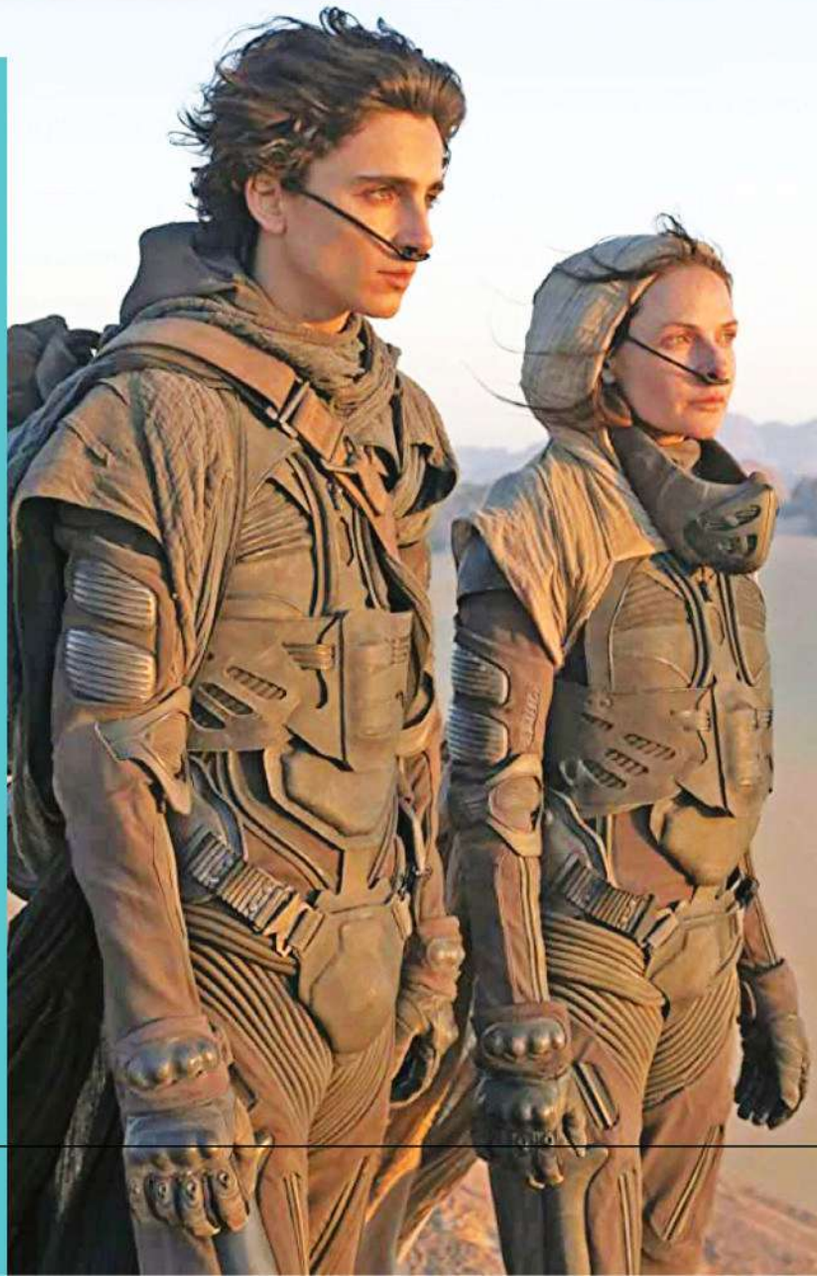
The desert planet Arrakis, the focus of the *Dune* series, orbits the star Canopus, which you'll find in the southern celestial hemisphere in the constellation of Carina. Canopus is the second-brightest star in the sky, outshone only by blazing Sirius. It lies 310 light years away from Earth.

DELTA PAVONIS

House Atreides' beautiful ocean homeworld, Caladan, orbits this star, found in the southern constellation of Pavo, 20 light years from Earth.

36 OPHIUCHI

Mortal enemies of the Atreides, the Harkonnens come from the polluted and ruined world Giedi Prime, which orbits this fifth-magnitude triple star system in the constellation of Ophiuchus. The star was given the name Guniibuu by the International Astronomical Union in 2018.



THE WORLDS OF DUNE

In Frank Herbert's sprawling *Dune* saga, a young Paul Atreides discovers he's destined to fight and replace a cruel emperor before eventually leading a bloody, galaxy-spanning crusade to become one of the most powerful rulers ever seen.

© Getty (Star Trek: CBS Photo Archive) / Alamy: Warner Bros Pictures; Pictorial Press Ltd

OTHER CELESTIAL SCIENCE-FICTION LOCATIONS

VEGA

With a magnitude of 0.0, making it the fifth-brightest star in the sky, Vega is a blue giant star in the northern constellation of Lyra. It's also the star that radio astronomer Ellie Arroway detects alien signals coming from in the film *Contact*. Only 25 light years away from us, Vega has been studied extensively by astronomers, and a dusty disc has been detected around it.

ANTARES

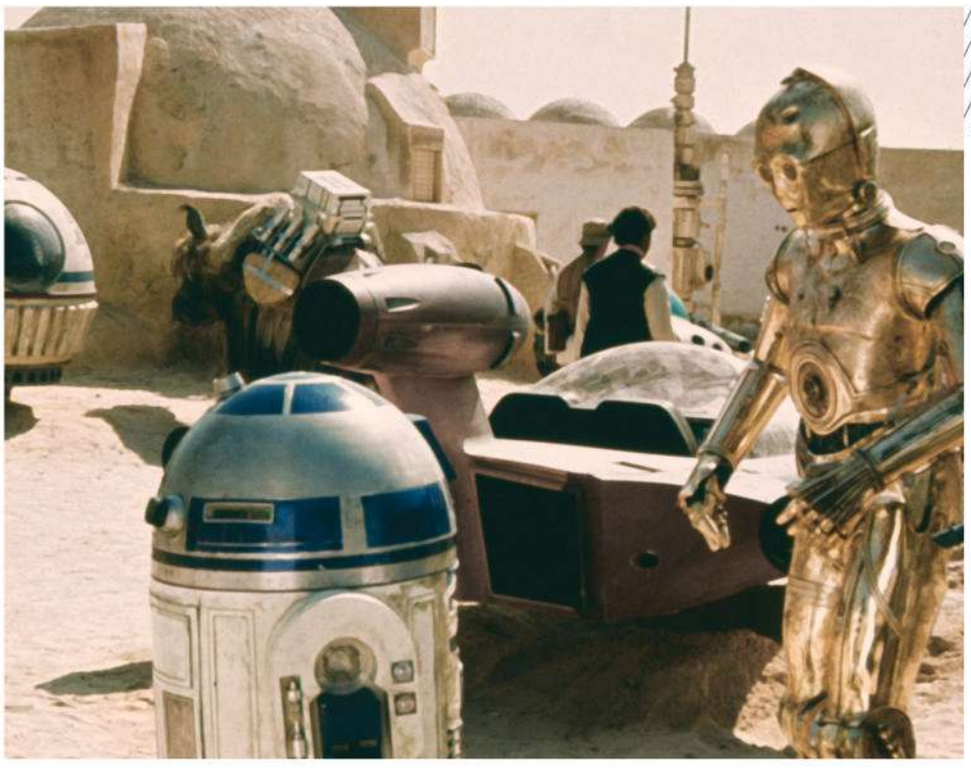
First-magnitude Antares is the brightest star in Scorpius. It's a deep orange-red colour to the naked eye. Lying 550 light years from Earth, Antares is an enormous supergiant star many times the size of our Sun. According to some writers, Antares is the star which Krypton, Superman's homeworld, orbited before its destruction.

RUKBAT

Fans of Anne McCaffrey know Rukbat, a fourth-magnitude blue-white star 182 light years away, as the setting for her epic tales of the Dragonriders of Pern, the descendants of the original colonists who settled the planet Pern, only to lose contact with Earth and then fall back into an almost-medieval civilisation. Rukbat lies beneath the famous Teapot asterism in Sagittarius.

ZETA RETICULI

This magnitude +5.5 star was the home star system of the Chigs, who waged a war with humankind in the 1990s TV series *Space: Above and Beyond*, but is probably better known as the star system visited by the ill-fated alien-fodder crew in several of Ridley Scott's blockbuster *Alien* films. It can be found 39 light years from Earth in the constellation Reticulum.



© Getty; (Star War; Screen Archives) / Alamy (Alien: FOX; SNAP)

THE WORLDS OF STAR WARS

None of the star systems or planets featured in the *Star Wars* stories can be seen in our sky. Why? The clue is in the title crawl: *Star Wars* takes place a long time ago in a galaxy far, far away. But if you want to see a real distant galaxy this month, all you have to do is go out on a clear night. Out of the corner of your eye you'll see a smudge of light down to the lower right of the 'W' of Cassiopeia. This is Messier 31, the Andromeda Galaxy, a spiral galaxy even bigger than our Milky Way that's so far away we see it as it was over 2 million years ago...

THE STORIES, STRATEGIES, HEROES & MACHINES

www.historyanswers.co.uk

HISTORY of WAR

ON SALE NOW

Available from all good newsagents and supermarkets

Hitler's Hangman > Bradley IFV > Winged Hussars > Trench Assaults > Yugoslav Wars

GREAT BATTLES | **MILITARY MACHINES** | **HEROES OF WAR** | **SECRETS & INSIGHT** | **INCREDIBLE PHOTOS**

BUY YOUR ISSUE TODAY

Print & digital subscriptions available at

www.magazinesdirect.com

facebook.com/HistoryofWarMag twitter.com/@HistoryofWarMag

FOCUS ON

‘HIDDEN’ PHOTONS COULD SHED LIGHT ON MYSTERIOUS DARK MATTER

A new experimental technique places constraints on a potential candidate for dark matter called ‘dark photons’

Reported by Robert Lea

A new method could help scientists shed light on the universe’s most mysterious substance by narrowing down the hunt for a particular dark matter candidate – hidden ‘dark photons’. Dark matter comprises about 85 per cent of the matter content of the universe, yet because it doesn’t interact with light or does so only very weakly, it remains effectively invisible. The fact that dark matter doesn’t seem to interact electromagnetically means scientists know it can’t be made up of the atoms that comprise the ‘normal’ matter that makes up stars, planets and our bodies. Dark photons were initially suggested as a dark matter candidate because they would weakly interact with ordinary photons, meaning they could have played a role in heating up the early universe. This action would explain why the cosmic web, a large-scale structure in the universe linking together galaxies, was hotter than predicted when observed by the Hubble Space Telescope.

Now, researchers from the California Institute of Technology have come up with a new detection method for dark photons. And while this new strategy hasn’t yet turned up any of the hypothetical particles, it has placed constraints on their characteristics, which will aid future searches. “The sensitivity of a hidden photon dark matter experiment depends on the strength of the dark matter signal compared to the smallest signal you can detect,” team member Nikita Klimovich, a researcher at Oxford University’s Department of Physics, said. “For hidden photon searches, the amplitude of the dark matter signal scales with the area of the metal dish used, while the minimal detectable signal level is largely determined by the noise level of the amplifiers used to read out the antenna.”

The inspiration for the team’s dark photon search comes from a previous attempt to hunt for hidden dark matter called the SHUKET experiment, which uses an electromagnetic telescope. “Previous searches that inspired this work, like the SHUKET experiment, generally aimed to maximise the signal strength through having a very large dish while using the best commercially available low-noise amplifiers they had access to,” Klimovich explained.

The team took a different approach in the new study, using quantum-limited amplifiers rather than off-the-shelf amplifiers and conducting their dark photon hunt at incredibly low temperatures. While this allowed the scientists to significantly reduce the minimal signal levels they could detect compared to other experiments using off-the-shelf technology, it came with a major drawback. The small vacuum-insulated environment of the cryostat device the scientists used to cool their apparatus severely limited the size of the spherical metallic dish they could use in their search.

Though this meant a much lower signal than that detected by SHUKET and other dark matter-hunting experiments, the team hoped that this disadvantage would be offset by the increased sensitivity of the measurements they collected. “If a hidden photon existed with a mass corresponding to the frequency range we were sensitive to, we should see a small excess lump of power coming from the dish compared to the reference,” Klimovich said. “Because we saw no such signal, we could set a new upper limit on the coupling of such a hidden photon particle to the electromagnetic field based on the smallest signal level we would have been able to detect.”

While the signal of dark photons wasn’t present in the team’s measurements, the approach taken by the scientists has placed stringent new constraints on theoretical hidden photons. As the search for dark matter candidates continues, these constraints could eventually play a role in the discovery of dark photons and solving the dark matter mystery.

WHAT DO WE KNOW ABOUT DARK MATTER?

It's the majority of matter
Invisible dark matter makes up 80 per cent of the mass in the entire universe.

It could be a new particle
Dark matter could be an undiscovered particle that hardly interacts with normal baryonic matter or radiation.

It affects light
Because of general relativity, dark matter acts as a gravitational lens and 'bends' light.

It could be an axion
Evidence for WIMPs is weakening, giving ground to axions as a possible alternative.

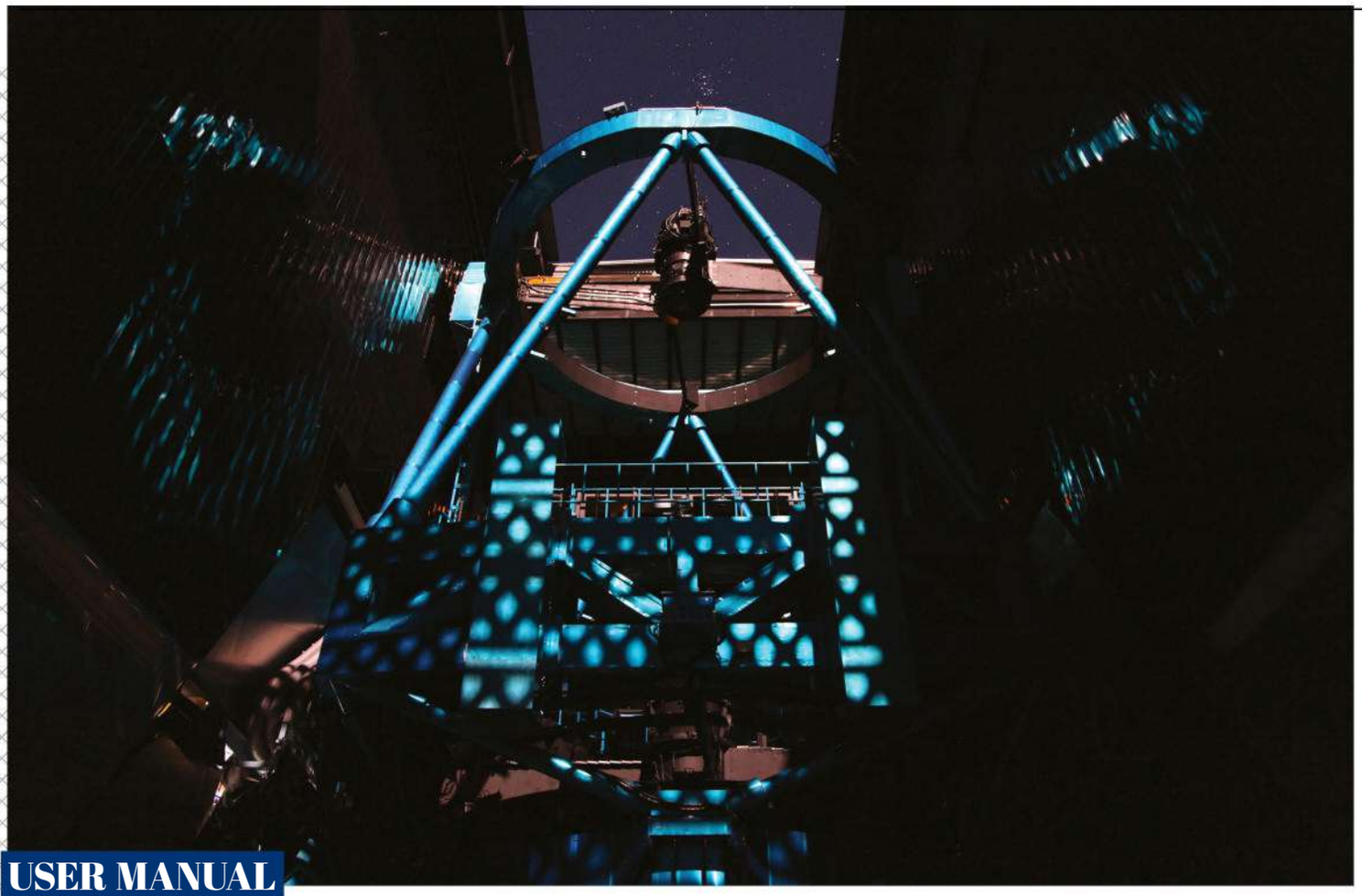
Newton's laws may need modifying
One alternative to dark matter is tweaking Newton's laws so they behave differently at galactic edges.

It could be a WIMP
Weakly Interacting Massive Particles formed after the Big Bang could be one explanation.

It's long lived
Axion dark matter could last 3,000 trillion years – roughly 220,000 times the current age of the universe.

It forms the universe's structure
Scientists think galactic clusters form in an existing 'dark matter web', forming the universe's large-scale structure.

© Getty



USER MANUAL

SUBARU TELESCOPE

SPECS

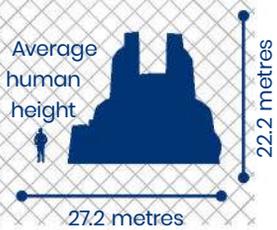
First light: January 1999

Primary mirror size: 8.2 metres (26.9 feet)

Primary mirror thickness: 20 centimetres (7.9 inches)

Location: Mauna Kea Observatory

Operator: National Astronomical Observatory of Japan



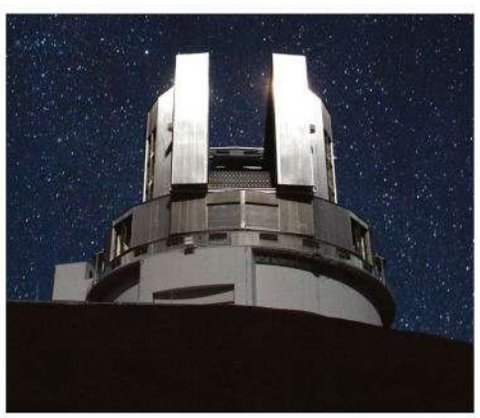
Sitting on top of the dormant volcano Mauna Kea in Hawaii, the Subaru Telescope takes advantage of one of the best astronomical observation sites on the planet. When the National Astronomical Observatory of Japan (NAOJ) commissioned the telescope in 1991, the organisation set out to build the best optical and infrared telescope possible, capable of discovering the secrets of the cosmos. And although 'Subaru' is a name commonly associated with automobiles, it originates from the Japanese name for the young cluster we know as the Pleiades (Messier 45). Not only is it another name for the 'Seven Sisters' in the constellation of Taurus, it also means 'tie together' in Japanese.

Construction began at the Mauna Kea site in June 1992 and was completed in December 1998, with scientific observations starting in January 1999. Some of the first light observations included the Orion Nebula (Messier 42), the spiral galaxy NGC 4051 and Abell 851. The construction process was a long and arduous journey. Engineers and scientists wanted to create the thinnest primary mirror possible, combine it with the latest technological advancements and enclose it within a state-of-the-art protective cylindrical dome that helps minimise air turbulence within the telescope's enclosure.

The product of such hard work and determination is one of the largest optical reflector telescopes, fitted with an impressive 8.2-metre (26.9-foot) single primary mirror within a Ritchey-Chrétien optical system. The

The Subaru Telescope has a focal length of 15 metres (49.2 feet)

The Pleiades and Jupiter glistening above the telescope



ANATOMY OF THE SUBARU TELESCOPE

The observatory's cameras and spectrographs span a range of wavelengths, utilising four focal points

1 Primary mirror
The primary mirror is 8.2 metres (26.9 feet) in diameter, coated in ultra-low thermal expansion glass.

2 Secondary mirror
1.3 metres (4.3 feet) in diameter, the secondary mirror is used to redirect the collected light to the Nasmyth foci without the need for coolant.

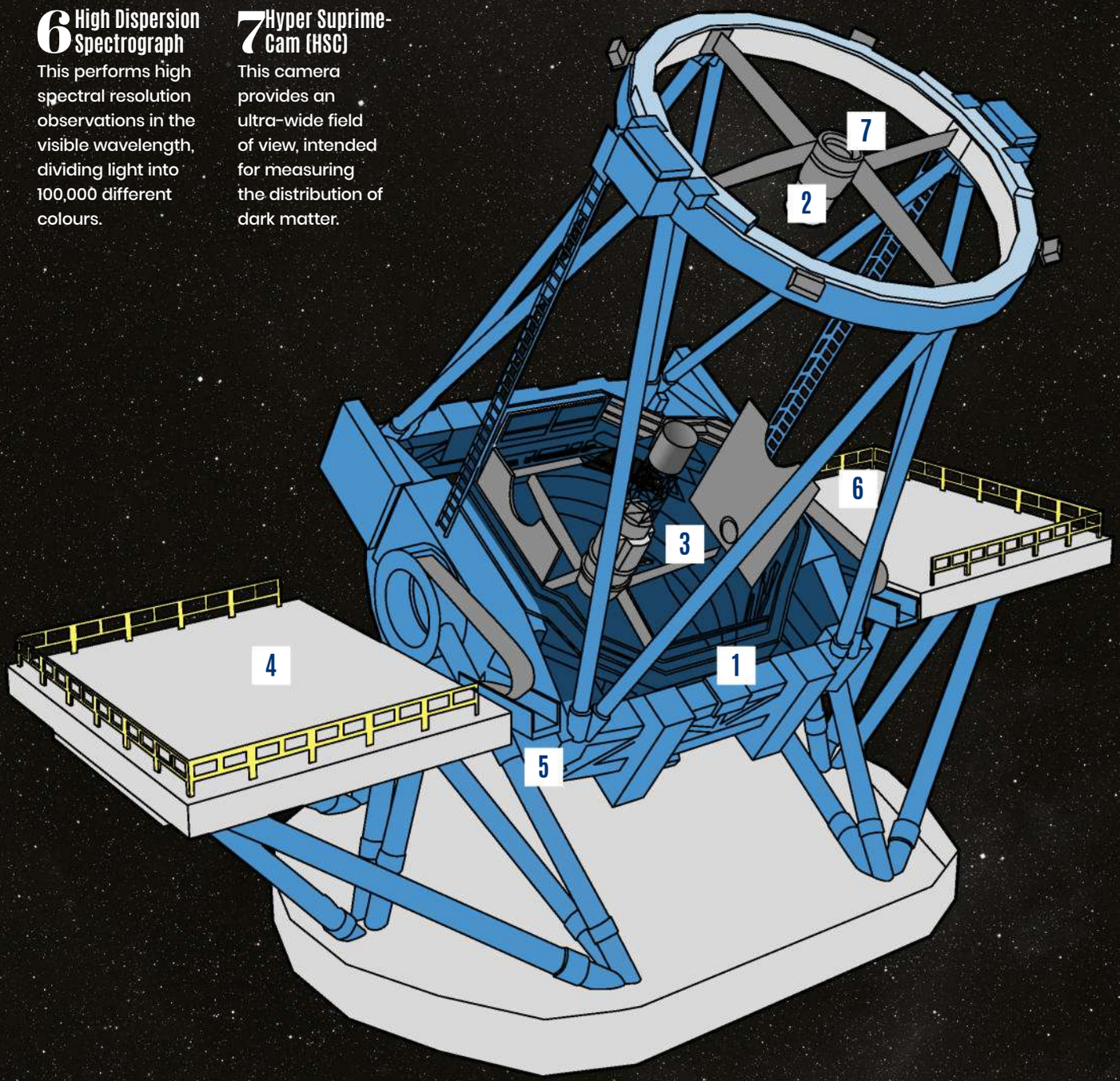
3 Tertiary mirrors
The tertiary mirrors are used to split the light into optical and infrared, directing it into the correct focus point.

4 Infrared Camera and Spectrograph (IRCS)
Creates images of the chemical compositions of distant targets, among other science.

5 Faint Object Camera and Spectrograph (FOCAS)
This highly sensitive instrument is dedicated to the observation of very faint celestial objects.

6 High Dispersion Spectrograph
This performs high spectral resolution observations in the visible wavelength, dividing light into 100,000 different colours.

7 Hyper Suprime-Cam (HSC)
This camera provides an ultra-wide field of view, intended for measuring the distribution of dark matter.



© Adrian Mann; NAOJ.

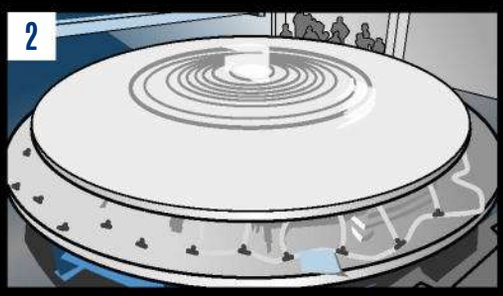
CONSTRUCTING THE SUBARU TELESCOPE

1 Foundation

Before the optics arrived, they needed a home to go to, hence the concrete pier and the control room needed to be constructed first.

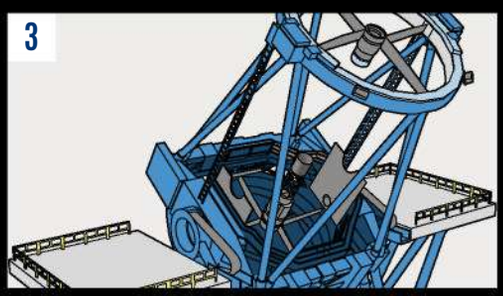
2 Creating the centrepiece

The primary mirror is made from ultra-low expansion glass and coated in aluminium, having taken three years to cast.



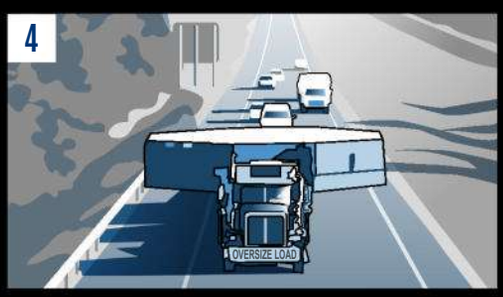
3 Subaru's sturdy structure

The rest of the telescope was constructed in its enclosure, consisting of the main structure and the mechanics.



4 Finishing touches

Final processing and polishing took four years to complete. It was then carefully transported via land to the summit of Mauna Kea.



5 Commence observations

Once everything was assembled within the dome, first light was received and vital scientific observations began in 1999.

mirror was carefully designed to provide the highest possible resolving power. This attention to detail results in an average surface error of just 0.012 micrometres - equivalent to about 0.0002 per cent the thickness of a human hair.

There are four focal points to the Subaru Telescope. Each of these focal points has carefully selected cameras and spectrographs to allow for the observation of the greatest range of cosmic events. The prime focus point is situated at the tip of the telescope's 'nose'. This region has an impressive 870-megapixel optical camera as well as a wide-field spectroscopy system able to image over 100 objects at once.

Lower towards the base there are two Nasmyth foci on opposite ends of the telescope – one collects optical light and the other infrared. Underneath the telescope is the Cassegrain focus, and this can have different instruments attached depending on the research goals. The three Cassegrain instruments are the Faint Object Camera and Spectrograph (FOCAS), the Multi-Object Infrared Camera and Spectrograph (MOIRCS) and the Cooled Mid Infrared Camera and Spectrograph (COMICS).

While the Sun is out, astronomers must plan which targets they intend to observe and then determine which instruments are to be used. This is when engineers use the Cassegrain Instrument Automatic Exchanger (CIAX) to swap over these hefty pieces of Cassegrain apparatus in roughly two hours. The Top Unit Exchanger helps in the exchange of the secondary mirrors

VITAL STATISTICS

555 tonnes – Weight of the telescope structure

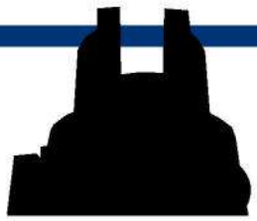
8.2 metres – Diameter of the primary mirror

Seven years – Time taken to construct the telescope

13 – Number of telescopes at Mauna Kea Observatory

HEAD TO HEAD

The Extremely Large Telescope (ELT) will have an enormous 39-metre (128 feet) primary mirror, dwarfing Subaru once completed. With first light planned for 2028, the ELT will be the world's biggest eye on the sky. Both telescopes will observe in optical and infrared, but the ELT will have a significantly higher resolving power as a result of its incredible design and technology, revolutionising our understanding of the cosmos.



Subaru
8.2 metres (26.9 feet)

ELT
39 metres
(128 feet)

and the Hyper Suprime-Cam (HSC). The HSC replaced the original Subaru Prime Focus Camera in 2012 and consists of 116 highly sensitive CCDs to provide an impressive field of view that's seven times wider than its predecessor.

Subaru's uniqueness and collaborations with other worldwide organisations mean the telescope has been at the heart of scientific discoveries for many years. NAOJ was also involved in the follow-up observations of the two merging neutron stars that created the gravitational wave emission formally known as GW170817. The Subaru Telescope was one of the many telescopes that turned its top-tier optics to the constellation of Hydra to find the visible counterpart of the gravitational wave detection. This is just one example of the groundbreaking discoveries that Subaru has made or contributed to throughout the years. Subaru hasn't just focused on the depths of the universe, though. It has also provided us with valuable images of objects within our Solar System. Using COMICS, Subaru's mid-infrared imaging was used to aid NASA's Juno spacecraft, providing information about the temperature distribution of Jupiter.

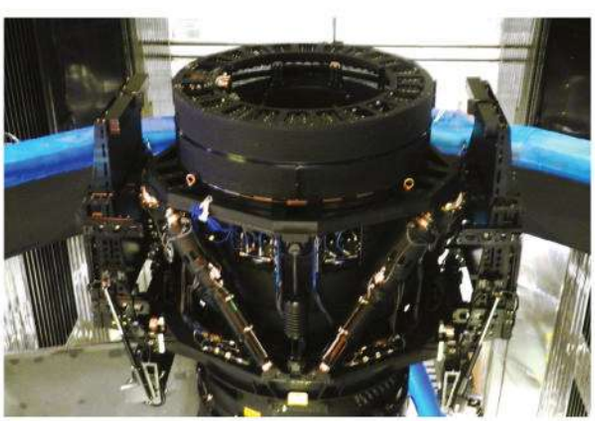
NAOJ continues to maintain and improve the telescope to an incredibly high standard, establishing itself as one of the world's best ground-based optical telescopes. Not only does it have the finest optics, technologies and engineers dedicated to its maintenance, but its prime location on Mauna Kea provides astronomers with around 240 clear nights a year. This is in part why the Subaru Telescope remains pivotal in the role of understanding the universe.

"NAOJ continues to maintain and improve the telescope to an incredibly high standard"

TOP TECH

SUBARU'S HYPER SUPRIME-CAM

The HSC is a much needed upgrade from the Subaru Prime Focus Camera, with 106 more CCDs then its predecessor, totalling 116. 104 of these are main science CCDs, four are used for autoguiding and eight are for autofocusing. To keep the camera in optimal condition, it's kept at a freezing -100 degrees Celsius (-148 degrees Fahrenheit). It's attached to the prime focus of the Subaru Telescope and provides a more refined field of view of 1.5 degrees of the night sky – equivalent to fitting nine full Moons within one of its images.



SWAPPING THE CASSEGRAIN INSTRUMENTS

1 Preparing for the night ahead
Astronomers must do their research and determine which instrument is best suited for their observational needs on a particular night.

2 Manoeuvring with the CIAX
Two tonnes is beyond the carrying capabilities of the maintenance engineers, so the Cassegrain Instrument Auto Exchanger (CIAX) is deployed.

3 Communicating with the cart
All communications between the cart and the telescope are done via a wire, which is attached to a fishing pole to help movement.

4 Successful swap
The CIAX transports the detached instrument to the standby room. It then brings in the intended instrument for the night and carefully attaches it.

SPECIAL SUBSCRIPTION OFFER

SUBSCRIBE AND GET TWO FREE BOOKS

WORTH £31

Reasons to subscribe...

- Brilliant value - save on the cover price
- Free copy of **Understanding Astrophysics** and **Book of the Moon**
- Delivered direct to your door
- Never miss an issue
- Exclusive subscriber-only covers

Subscribe now

www.magazinesdirect.com/spacesubs
or call 0330 333 1113 and quote C45R

PRINT ONLY

Delivered direct to your door for £11.50 every three months

PRINT AND DIGITAL

Delivered direct to your door and device for £15.25 every three months

***Terms and Conditions:** Offer closes 31 January 2024. Offer open to new UK subscribers only. Savings are based on cover price and annual subscription rate. We will notify you in advance of any price changes. Please allow up to six weeks for delivery of your first subscription issue, or up to eight weeks overseas. Payment is non-refundable after the 14-day cancellation period unless exceptional circumstances apply. Gifts only available to new subscribers on the UK mainland. Your gift will be delivered separately within 60 days after your first payment has cleared. This offer is not available on overseas or digital subscriptions. In the unlikely event that we run out of this gift, we promise to offer you an alternative gift of the same or greater value. For full terms and conditions visit **www.magazinesdirect.com/terms.**For enquiries please call: +44 (0) 330 333 1113. Lines are open Monday to Friday 08.30 to 19:00 and Saturday 10:00 to 15:00 UK time or e-mail: **help@magazinesdirect.com.** Calls to 0330 numbers will be charged at no more than a national landline call, and may be included in your phone provider's call bundle.

INSTANT EXPERT

PLANET FORMATION: IS IT TURBULENT OR TRANQUIL?

How gaseous and rocky bodies form around young stars

There are so many different types of planets – terrestrial planets like Earth, gas giants like Jupiter and dwarf planets like Pluto – but every cake must start with simpler ingredients, and planets are no exception. For planets these are the gases and minute dust particles that circled the infant Sun in the vast flattened disc we call the 'protosolar nebula'. Laboratory studies of meteorites and astronomical studies of protostellar discs around nearby baby stars have also told us that however it happened, planets must form quickly, astronomically speaking, within a few million years. This revolutionised our thinking about how planets form.

The small particles in the protosolar nebula can stick together and form pebble-sized particles, but the process can't continue indefinitely to larger and larger sizes because as pebbles grow they strike each other at greater and greater speeds and end up demolishing each other. But when there are enough pebbles in a cloud, that cloud will collapse in upon itself due to its own gravity, and just like that you get a planetary building block – a planetesimal. The best part is that we don't have to go back in time to see one; we just have to go to the Kuiper Belt, beyond the orbit of Neptune.

On 1 January 2019, NASA's New Horizons spacecraft flew by a Kuiper Belt object called Arrokoth. This body was chosen for the flyby because small worlds in this part of deep space have been left more or less undisturbed since the Solar System's inception 4.5 billion years ago. What New Horizons saw, however, was actually two bodies, each flattened like lentils and gently assembled into a contact binary. No evidence of a violent merger or collision is evident. This is precisely what is predicted in computer simulations of planetesimal formation in a collapsing pebble cloud, which is that binaries often form and gently merge.

Once you have planetesimals, it's game on. Planetesimals can collide, merge and accrete more pebbles as they grow to larger sizes. If they get really big – becoming protoplanets – they can attract gas directly from the nebula and become giant planets like Jupiter. Protoplanets themselves can also collide with spectacular results, with one example being the formation of Earth's Moon.

BIO
PROFESSOR WILLIAM B. MCKINNON

McKinnon is a professor of Earth and planetary sciences at Washington University in St Louis, Missouri. His primary research focuses on the icy bodies that reside in the outer Solar System in a region known as the Kuiper Belt. However, this is just a part of his much wider understanding of the formation and evolution of the entire Solar System.

4

5

1 Starting from gas
From tiny moons to supermassive black holes, every object in the universe was initially formed from a cloud of gas and dust.

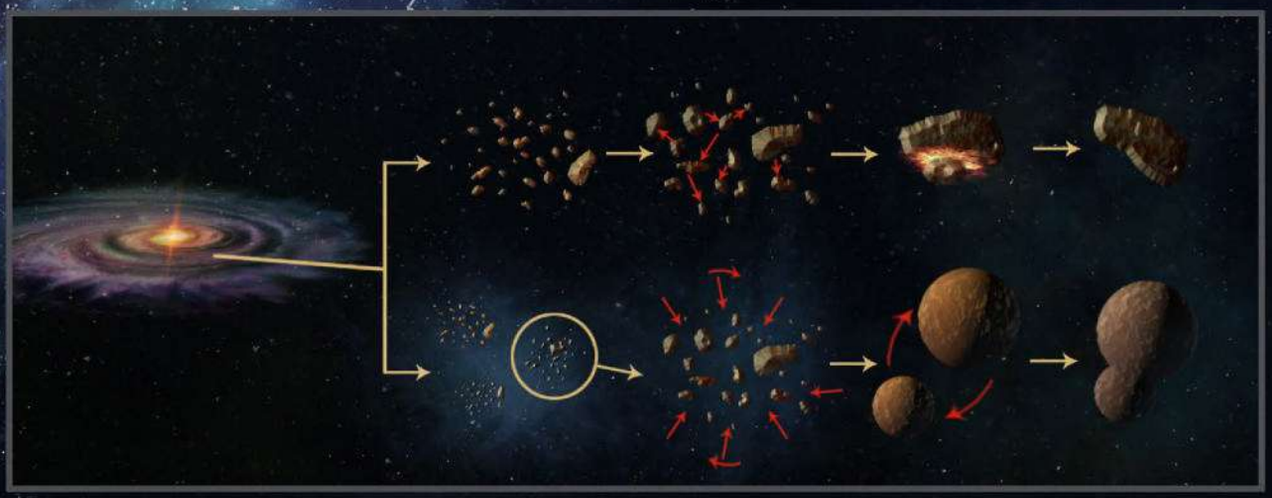
2 Gas to pebbles
After the host star has formed, the leftover gas provides the fundamental ingredients for planetary formation, beginning with the accretion of pebble-sized particles.

3 Pebbles to a rocky swarm
The gas around the pebble-sized particles will then herd the particles into great swarms and clouds, which then collapse under their own gravity.

4 Clouds of pebbles to planetesimals
The formation of planetesimals is much less violent than the public perception, with observations of Kuiper Belt object Arrokoth revealing that objects merge gently.

5 Planetesimals to planets
The planetesimals then attract the attention of more leftover debris, which then creates the final form of a planet and the base for life.

2



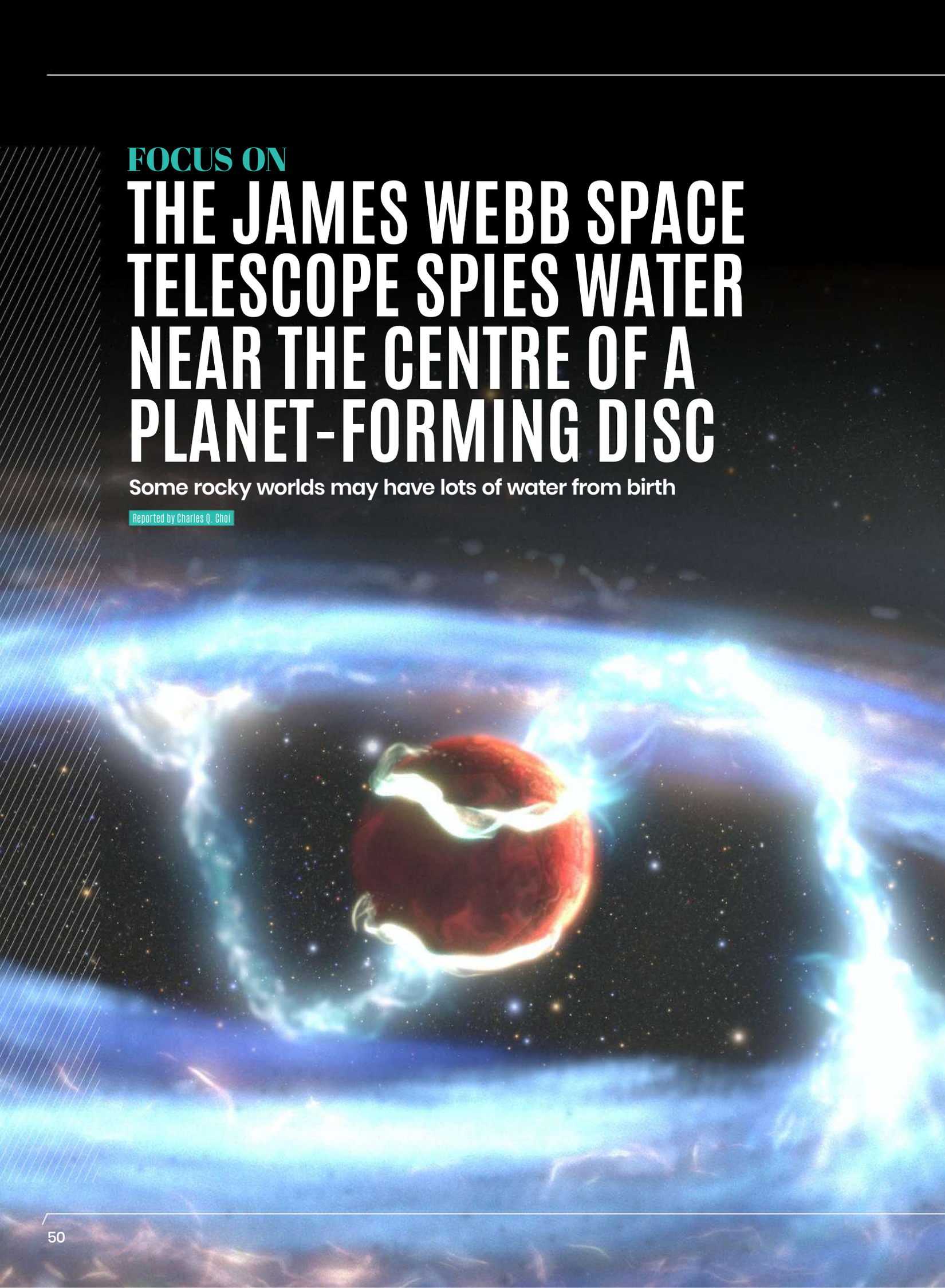
© Nicholas Forder

FOCUS ON

THE JAMES WEBB SPACE TELESCOPE SPIES WATER NEAR THE CENTRE OF A PLANET-FORMING DISC

Some rocky worlds may have lots of water from birth

Reported by Charles Q. Choi



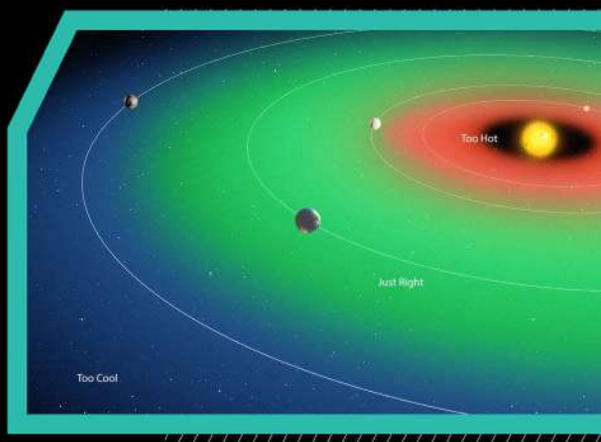
Astronomers have discovered that rocky alien worlds could possess large amounts of water from the moment they form. Life is found virtually wherever there is water on Earth. As such, the search for habitable exoplanets has mainly focused on hunting for the presence of water. Previous research suggested that the newborn Earth got a lot of its water from water-bearing asteroids bombarding our young planet's surface after it formed. Now scientists may have discovered evidence that water could also serve as one of the initial ingredients of rocky planets, available from birth.

Researchers focused on the young star PDS 70, located about 370 light years from Earth. About three-quarters the mass of the Sun, PDS 70 is only about 5.4 million years old, compared to our Sun's age of about 4.6 billion years. "PDS 70 is a star similar to our Sun, just younger and cooler," study lead Giulia Perotti, an astrophysicist at the Max Planck Institute for Astronomy, said. "By observing it, we can trace back how the planets in our Solar System formed and what their chemical composition was before they fully formed."

Using the Mid-Infrared Instrument (MIRI) on NASA's James Webb Space Telescope, the scientists discovered water near the centre of the planet-forming disc of gas and dust surrounding PDS 70, in the form of hot vapour. "Our result shows that water is present in the inner disc of this iconic system, where planets similar to Earth may be assembling," Perotti said.

In our Solar System, this central zone is where Earth and the other rocky planets formed. These new findings suggest that any rocky planets originating in PDS 70's central zone would draw from a substantial reservoir of water, improving their changes of habitability later on. PDS 70 is the first relatively old planet-forming disc where scientists have discovered water. Previous research failed to detect water in the central regions of discs of similar age, leading astronomers to speculate that harsh radiation from newborn stars might destroy nearly all water. But these new findings challenge that idea. "In the PDS 70 system, there's quite a lot of water available during the process of rocky planet formation," study co-lead Thomas Henning, an astrophysicist at the Max Planck Institute for Astronomy, said.

So far the scientists haven't actually detected any planets near the centre of PDS 70's disc. Discovering any such worlds requires larger telescopes, such as the Atacama Large Millimeter/submillimeter Array (ALMA) in Chile, Henning noted. Still, they have detected two gas giant planets farther out, dubbed PDS 70 b and c. The gravitational influence of these giant worlds is actually preventing the influx of ice-rich rock from the outer parts of the disc to its centre, Henning said. One possible explanation for the presence of this water is that it was left over from a water-rich nebula that gave birth to the PDS 70 system, with dust and other material in the planet-forming zone potentially shielding this water from the star's destructive radiation. Another possibility is that oxygen and hydrogen gas entering the outer rims of the PDS 70 disc might have combined to form water vapour that could in turn drift closer to the star. Future research could examine more planet-forming discs around young stars to see if PDS 70 is an unusual exception, Perotti said.



Liquid water can only exist within the habitable zone

© Getty Images

NEXT GIANT LEAP

We've gone from biplanes to Falcon 9 in a century. What will the next 100 years bring?

Written by Luis Villazon

106 years ago, the Smithsonian Institution gave Robert H. Goddard a $5,000 grant to pursue his early experiments with rockets. Today, NASA's budget is $25.4 billion (£19.9 billion), and private companies spend even more building and launching commercial satellites. The next 100 years will see the privatisation of space, not just of telecommunications, but also basic research and exploration. New ways of reaching space and reusing spacecraft will dramatically cut the cost per kilogram of payloads, and advances in robotics and guidance will make the journeys much safer. Space travel won't just be for astronauts than air travel is just for pilots.

All About Space chats with experts in different areas of aerospace research to try and get a glimpse of the progress that could be made in the next century. But extrapolating existing trends is always risky – 100 years ago, who would have predicted YouTube or the GPS satellite network? But even the most cautious fortune-tellers agree that our great grandchildren will quite routinely journey further and faster than the most experienced astronauts working today. The horizons of our world are about to expand in a way that hasn't been seen since Ferdinand Magellan first set off to circumnavigate our tiny blue world.

Space elevator

A LIFT TO THE MOON

A working space elevator has been the Holy Grail of space travel since Konstantin Tsiolkovsky published the idea in 1895. But the biggest hurdle so far has been finding a material strong enough to withstand the 50-gigapascal tension that the cable would need to handle. Large-scale carbon nanotube fibre currently has a tensile strength of just one gigapascal, and steel isn't much better at 4.8 gigapascals. Carbon nanotubes could become strong enough theoretically, but we're currently unable to assemble them. Recent studies found that even a single atom out of place could halve the strength of the entire cable. On the Moon, where the gravity is only one-sixth of Earth's, the stresses are much lower, and an elevator made of kevlar could be feasible. Scientists have managed to synthesise diamond threads, which are even stronger than carbon nanotubes, and boron nitride nanotubes which have self-healing properties, capable of repairing micrometeoroid damage.

An artist's impression of a space elevator looking down at Earth

John V. Badding, professor of materials science and engineering at Penn State University

"Conventional carbon nanotubes have not yet proved to have the strength that's predicted based on the ideal structure. This is most likely because of defects in them. [Diamond threads] offer a unique combination of extreme strength, flexibility and resilience. You also want it to not fail catastrophically."

Robots

HELPFUL HUMANOIDS IN SPACE

An uncrewed probe reaches the surface of Saturn's moon Titan. But instead of releasing a rover, 200 four-legged robots, each the size of a tennis ball, scuttle out. They can scout and probe the terrain independently, but they can also join together and reconfigure themselves to bridge chasms, scale cliffs, mine resources and assemble large structures. This is the concept of the self-transforming robot, developed for NASA by Professor Steven Dubowsky of the Massachusetts Institute of Technology. He predicts that within 40 years, these robots could have bodies made of intelligent nodes, connected by mechanical tentacles that can be disconnected and reattached in whatever arrangement they need. In 100 years, the robots will also be able to transform into a 3D printer that can print mechanical parts and electronics and build new robots.

An impressive future for humanoid robots awaits. Robots that are the same size and shape as us can fly in the same spaceships and use the same tools. Fully autonomous humanoids will be used as the vanguard for human colonisation missions to test habitation modules throughout the Solar System.

Dr Richard Osborne, chief technology officer at AstroAgency

"The progress will be considerable due to the breakthroughs in materials. Lighter, stronger materials based around graphene-type compounds are likely to play a major role, as will additive manufacture – 3D printing. The cost of access to space will go down; initially not much for single stage to orbital spaceplanes, but as more and more operational experience is built up of spaceplanes, more cost-effective vehicles will be developed."

Commercial spaceplanes

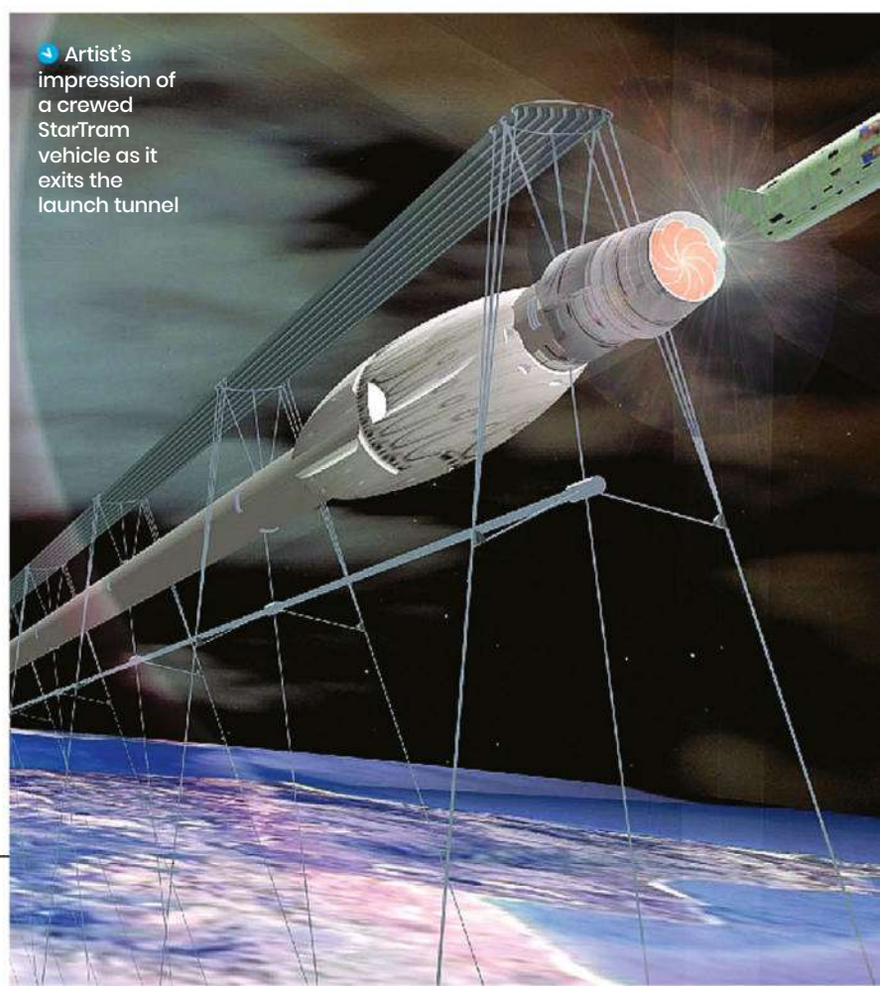
YOUR FLIGHT INTO SPACE

In the 1950s, commercial air travel was too expensive to be routine, but it wasn't out of reach either. By 2150 it will be the same for commercial passenger spaceflight. Today, only millionaires can afford a private flight into space, but by 2150 it could cost no more than a first-class airline ticket. Current reusable rockets, such as SpaceX's Falcon 9, can only return the first stage and the crew capsule to Earth – the upper stage isn't economical to recover. Spaceplanes such as Virgin Galactic's SpaceShipTwo and Skylon, designed by UK-based Reaction Engines, are more expensive to build and refuel, but they offer full reusability, which may make them cheaper. Richard Osborne, previously a systems consultant for Reaction Engines, predicts that the first single-stage-to-orbit spaceplanes will begin flight testing in 2030, and by 2070 we could see the next generation entering commercial service. These will use fully 3D-printed assembly techniques and more reliable autonomous guidance electronics. Commercial spaceplanes could offer a cheap shuttle service to a low-Earth orbit space station.

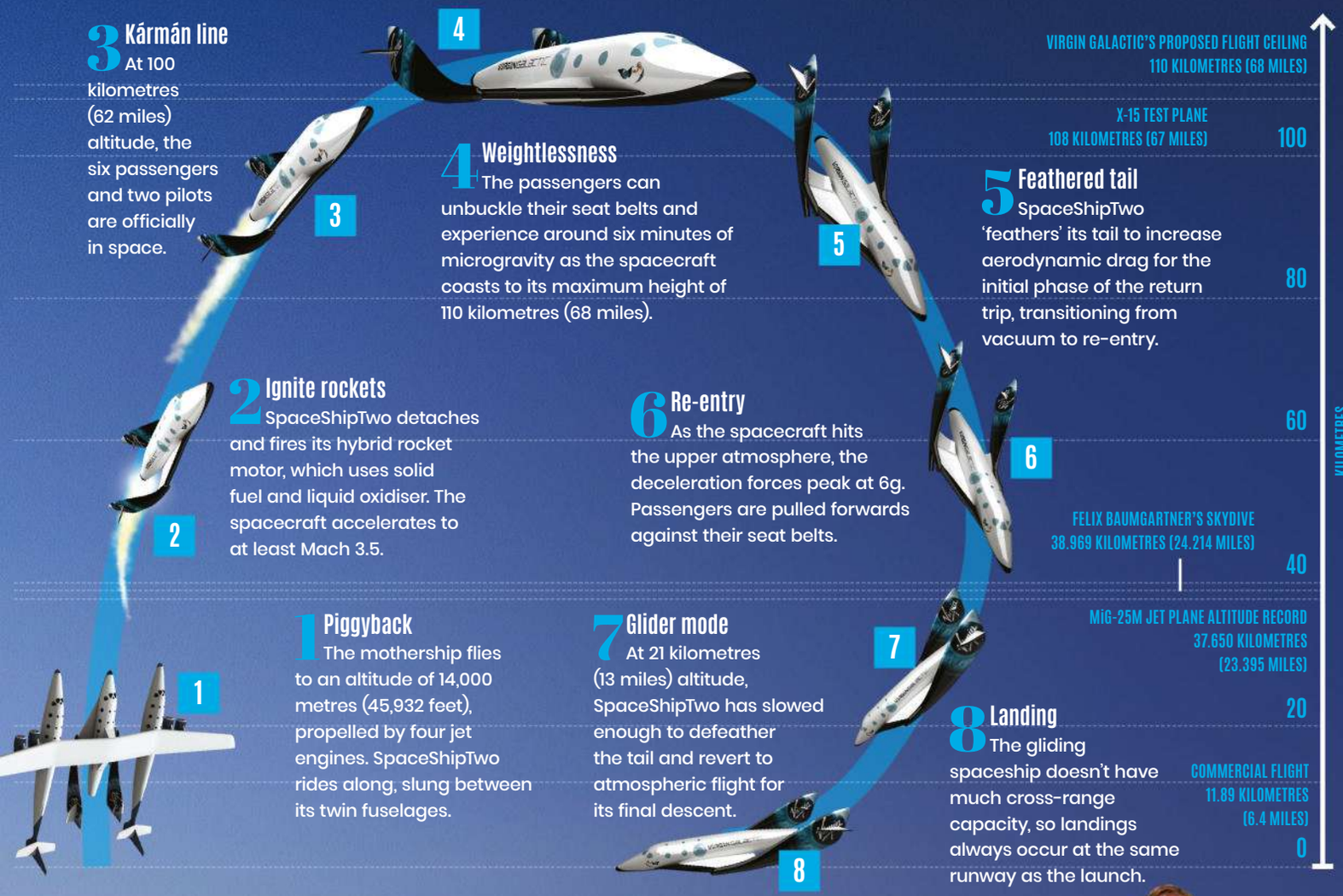
StarTram

A TRAIN INTO EARTH ORBIT

StarTram is a proposal for a maglev train track built inside a partially evacuated tube set on the side of a mountain. Cargo modules would be loaded through an airlock onto a carriage at the bottom of the track and then accelerated along the track before popping out of the far end. Even though the top is open to the atmosphere, it doesn't fill up with air because a magnetohydrodynamic pump ionises any air molecules that drift in – they are expelled by the magnetic field in the tube. NASA developed the StarTram concept in the 1990s in collaboration with James R. Powell and Gordon Danby, who invented superconducting maglev trains. It seems far-fetched, but this is just the design for the first-gen system. StarTram Gen-2 would extend the evacuated tube past the top of the mountain so that it hangs in thin air, supported by the magnetic levitation force supplied by superconducting cables carrying 220 million amps of electricity. This tube could carry payloads up to 22 kilometres (13.7 miles), where the air is much thinner. It's predicted that StarTram Gen-2 could send 4 million people into orbit per decade.



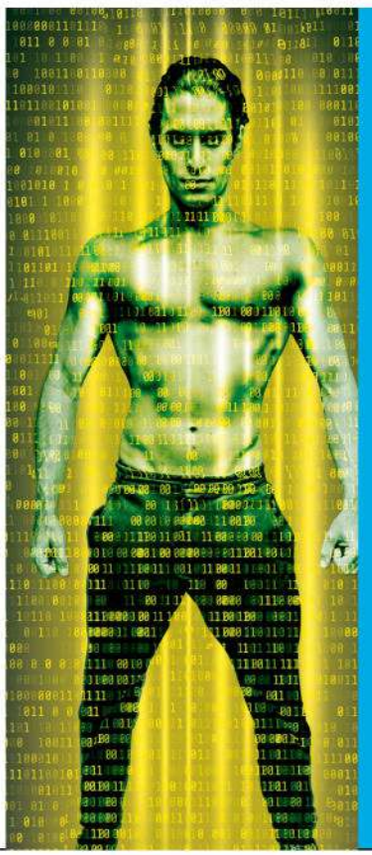
Artist's impression of a crewed StarTram vehicle as it exits the launch tunnel


3 Kármán line
At 100 kilometres (62 miles) altitude, the six passengers and two pilots are officially in space.
4 Weightlessness
The passengers can unbuckle their seat belts and experience around six minutes of microgravity as the spacecraft coasts to its maximum height of 110 kilometres (68 miles).
5 Feathered tail
SpaceShipTwo 'feathers' its tail to increase aerodynamic drag for the initial phase of the return trip, transitioning from vacuum to re-entry.
2 Ignite rockets
SpaceShipTwo detaches and fires its hybrid rocket motor, which uses solid fuel and liquid oxidiser. The spacecraft accelerates to at least Mach 3.5.
6 Re-entry
As the spacecraft hits the upper atmosphere, the deceleration forces peak at 6g. Passengers are pulled forwards against their seat belts.
1 Piggyback
The mothership flies to an altitude of 14,000 metres (45,932 feet), propelled by four jet engines. SpaceShipTwo rides along, slung between its twin fuselages.
7 Glider mode
At 21 kilometres (13 miles) altitude, SpaceShipTwo has slowed enough to defeather the tail and revert to atmospheric flight for its final descent.
8 Landing
The gliding spaceship doesn't have much cross-range capacity, so landings always occur at the same runway as the launch.
VIRGIN GALACTIC'S PROPOSED FLIGHT CEILING 110 KILOMETRES (68 MILES)
X-15 TEST PLANE 108 KILOMETRES (67 MILES)
FELIX BAUMGARTNER'S SKYDIVE 38.969 KILOMETRES (24.214 MILES)
MiG-25M JET PLANE ALTITUDE RECORD 37.650 KILOMETRES (23.395 MILES)
COMMERCIAL FLIGHT 11.89 KILOMETRES (6.4 MILES)
100
80
60
40
20
0
KILOMETRES

Teleportation

TRANSFERRING PARTICLES FROM ONE PLACE TO ANOTHER

Sadly, the *Star Trek* transporter isn't going to happen in the next 100 years. But there is another kind of teleportation that might still be available by 2123: quantum teleportation. This allows pairs of photons to be 'entangled' so that their quantum states are in perfect synchrony. When one of the photons is beamed to a distant location, its entangled twin can be used to detect any changes or corruption in the signal. Systems that use this property to create unbreakable encryption are already being used on Earth. In space, unhackable signals might be useful to prevent criminal or terrorist interference with crucial spaceflight communications. Quantum teleportation can also be used to correct ordinary signal noise and degradation, improving receiver sensitivity and allowing us to talk to probes that have travelled far beyond the reach of today's best antennae. It doesn't let us communicate faster than the speed of light, but it could give us lossless radio communications. The current challenge is that quantum entanglement breaks down when photons are transmitted a relatively short distance, but researchers are optimistic we'll be able to extend this.



Dr Wolfgang Tittel, AITF strategic research chair at the University of Calgary, Canada

"Quantum teleportation has no theoretical distance limit. However, to distribute quantum entanglement over arbitrarily large distances, you need quantum repeaters. Once you have distributed perfect entanglement, you can communicate signals by means of teleportation without degradation or malicious tampering."

Colonisation of the Moon, Mars and asteroids

LIVING ON ANOTHER WORLD

Crewed missions to Mars are expected to occur in the 2030s

Though we're getting closer with Artemis, we haven't sent humans to the Moon in more than 50 years, and if the first crewed missions to Mars arrive in the 2030s there will still be a long way to go before a permanent base can be established, let alone a colony. "Everything generally does take a lot longer than anticipated regarding space development," says Osborne. But even so, he predicts that by 2067, the Mars base will have expanded to colony size and a space habitat at the Earth-Moon Lagrange point L4 will be in the process of being constructed. As more people start living in space, the rate of colony building will accelerate. By 2110, Osborne expects there will be colonies on the Moon, Mars, on asteroids and within the Jovian system.

Ian Crawford, professor of planetary science and astrobiology at Birkbeck, University of London

"In the next 100 years I would be disappointed if there aren't at least scientific outposts on the Moon and Mars, some of which might have become largely self-sustaining and be on trajectories to become small colonies. I would also hope to see asteroid mining initiated within this period."

SPS-ALPHA

BEAMING SOLAR POWER BACK TO EARTH

Solar power on Earth only works during the day and is less efficient in cloudy weather. An array in space can collect solar power almost continuously and beam it safely down to Earth as low-density microwaves. It's a way to make solar panels work at night. Proposals for space-based solar power arrays have been around since the 1960s, but the trouble is that to be worthwhile they have to be huge. One early NASA project would have needed rockets capable of lifting 250 tonnes at a time into orbit, and hundreds of astronauts to assemble the full array. The Solar Power Satellite via Arbitrarily Large Phased Array (SPS-ALPHA) gets around this problem by turning the array into a self-assembling construction set.

A total of eight different module types – most weighing no more than 50 kilograms – would be launched in huge numbers over multiple rocket launches. Some of the modules work like miniature versions of the International Space Station's Canadarm, walking across the growing structure and fixing new modules into place. Once the core of the array is in place, SPS-ALPHA can begin beaming power to Earth, but new modules can be added over time to increase the size of the collecting area. Also, by beaming microwaves at developing hurricanes, SPS-ALPHA could weaken or divert their path, saving coastal communities from storm damage and power cuts.

1 Collection array
The 1,200-square-metre (12,916-square-foot) aperture array is built from over 200,000 modules, each one wirelessly networked to the others and capable of independently pointing itself.

2 Electricity generation
Power from the solar panels is carried through cables down a central truss to the wireless power transmission (WPT) array hanging below it.

3 WPT array
High-efficiency solid-state amplifiers convert electrical power into microwave energy, which is then beamed down to a ground station.

4 Invisible microwaves
Microwaves pass easily through air and water vapour. The beam is diffuse enough that it isn't harmful to plane passengers or birds.

5 Steering signal
A pilot signal from the ground is used by each module in the WPT array to adjust the pointing of the microwave beam.

6 Rectifying antenna
The ground antenna, several kilometres across, collects the microwaves and converts them back into electrical power to be fed into the local power grid.

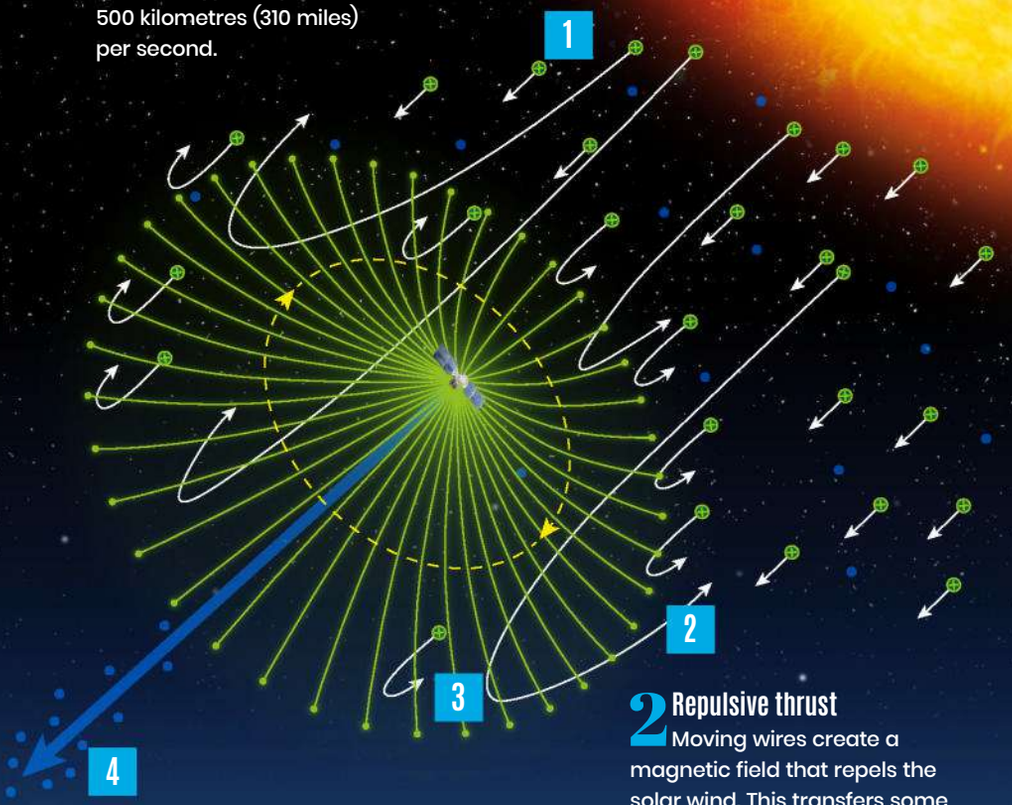
New propulsion systems

ELECTRIC SAILS AND BEAMED ENERGY

Missions to the edge of the Solar System and beyond need extremely efficient propulsion systems that can keep gently accelerating for years. Current ion engines wear out too quickly and can't generate enough electricity that far from the Sun, while solar sails stop accelerating by the time they reach the orbit of Jupiter because the solar wind gets too weak to push a relatively heavy foil sail. Electric sails will get around this by swapping a physical sail for a magnetic field. By using very thin charged wires to repel high-energy protons from the Sun, a spacecraft can generate an effective sail area of 600 square kilometres (232 square miles), allowing it to continue accelerating all the way to Pluto. Projections from NASA suggest that an electric sail craft could reach the edge of the Solar System in just ten years.

Beamed-energy propulsion operates over much shorter distances. It's designed to power payloads to space in a single reusable stage that doesn't need to carry fuel or oxidiser. Instead it simply expels an inert gas, heated to enormous pressure by the heat from a focused microwave beam array. Prototype thrusters have already been developed that have better thrust efficiency than the best rocket engines available today. With suitable ground-based power transmission and storage, this could be up and running well before the turn of the century.

1 Solar wind
Protons from the Sun continuously stream out into space at typical speeds of 500 kilometres (310 miles) per second.



2 Repulsive thrust
Moving wires create a magnetic field that repels the solar wind. This transfers some momentum from the protons to the spacecraft, propelling it.

3 Revolving wires
The sail consists of around 20 positively charged aluminium wires, each up to 30 kilometres (18.6 miles) long. The spacecraft spins to keep them stretched out like spokes.

4 Balancing charge
To keep the wires positively charged, electrons could be continually fired into space from an electron gun mounted at the front of the spacecraft.

5 Heat exchanger
A microwave-absorbing panel heats up when the beam strikes it, heating up the propellant gas and increasing the pressure of the exhaust jet.

6 Exhaust
The launch vehicle doesn't need bulky oxidiser or flammable fuel – just inert and non-polluting helium or argon propellant.

7 Focused beam
Using antennae and microwave mirrors, the array of beams is focused onto the launch vehicle, tracking it as it flies through the air.

8 Grid energy
Electricity from the power grid or renewable sources is stored in high-efficiency capacitors at the beaming station.

9 Microwave array
High-power microwave generators efficiently convert electricity to microwave beams that can be sent through the air with very little energy loss.

© Adrian Mann; Alamy; Shutterstock; NASA; Mars One; Virgin Galactic

FOCUS ON

OUR INFANT SOLAR SYSTEM MAY HAVE SURVIVED A NEARBY SUPERNOVA

Radioactive isotopes in meteorites suggest a stellar explosion erupted near the planets as they were forming

Reported by Robert Lea

A supernova that exploded close to our newly forming Sun could have destroyed what became our Solar System if it weren't for a shield of molecular gas. Scientists reached this conclusion by studying the isotopes of elements discovered in meteorites. These space rocks are pieces of asteroids that formed from material that was around when the Sun and then the planets of the Solar System formed. As such, meteorites are fossils of a sort, allowing scientists to reconstruct the evolution of the Solar System.

The research team found varying concentrations of a radioactive isotope of aluminium in meteorite samples. This information revealed that around 4.6 billion years ago, an additional amount of the radioactive aluminium entered our planetary backyard. The best explanation for such an injection of radioactive material is a nearby supernova blast, study team members said. Our infant Solar System therefore probably survived a supernova blast wave, according to the researchers led by National Astronomical Observatory of Japan astrophysicist Doris Arzoumanian. The birth cocoon of the Solar System likely acted as a buffer to this shock wave.

Supernova explosions occur when dying massive stars run out of the fuel for nuclear fusion and their cores can no longer support themselves against gravitational collapse. As the core collapses, a supernova is triggered that spreads the heavy elements the star has forged throughout its life into space. This material becomes the building blocks of the next generation of stars and planets – but the blast wave that carries it outwards can be strong enough to rip apart any newborn planetary systems that happen to be nearby.

Stars are born in giant clouds of molecular gas that are composed of dense tendrils or filaments. Smaller stellar bodies, like the Sun, form along these filaments, while larger stars, like the one that would have exploded in this supernova, tend to form at points where these filaments cross each other. Considering this, Arzoumanian and the team estimated that it would take around 300,000 years for the supernova shock wave to break up the dense filament shielding the infant Solar System.

Meteorites that are rich in radioactive isotopes broke apart from larger bodies like asteroids that were born in the first 100,000 years of the Solar System, while it was still in this dense filament. The cocoon would have acted to protect the forming Solar System from harsh radiation emitted from hot and massive stars called OB stars, something that could have negatively impacted the formation of planets like Earth. The new results suggest that as well as acting like a shield, the filament could have caught and channelled radioactive isotopes, bringing them into the region around the infant Sun.

The researchers believe that their findings could be crucial in understanding the formation and evolution of stars and their planetary systems. "This scenario may have multiple important implications in our understanding of the formation, evolution and properties of stellar systems," the team wrote in the study.

© Getty

FEED YOUR MIND

www.howitworksdaily.com

BUY YOUR ISSUE TODAY!

HOW IT WORKS

Print and digital subscriptions available at

www.magazinesdirect.com

Also available from all good newsagents and supermarkets

How It Works magazine | @HowItWorksmag | howitworks@futurenet.com | howitworksmag

MYSTERIES OF THE UNIVERSE

THE TWO-FACED STAR

With one side helium and the other hydrogen, the white dwarf Janus is baffling astronomers

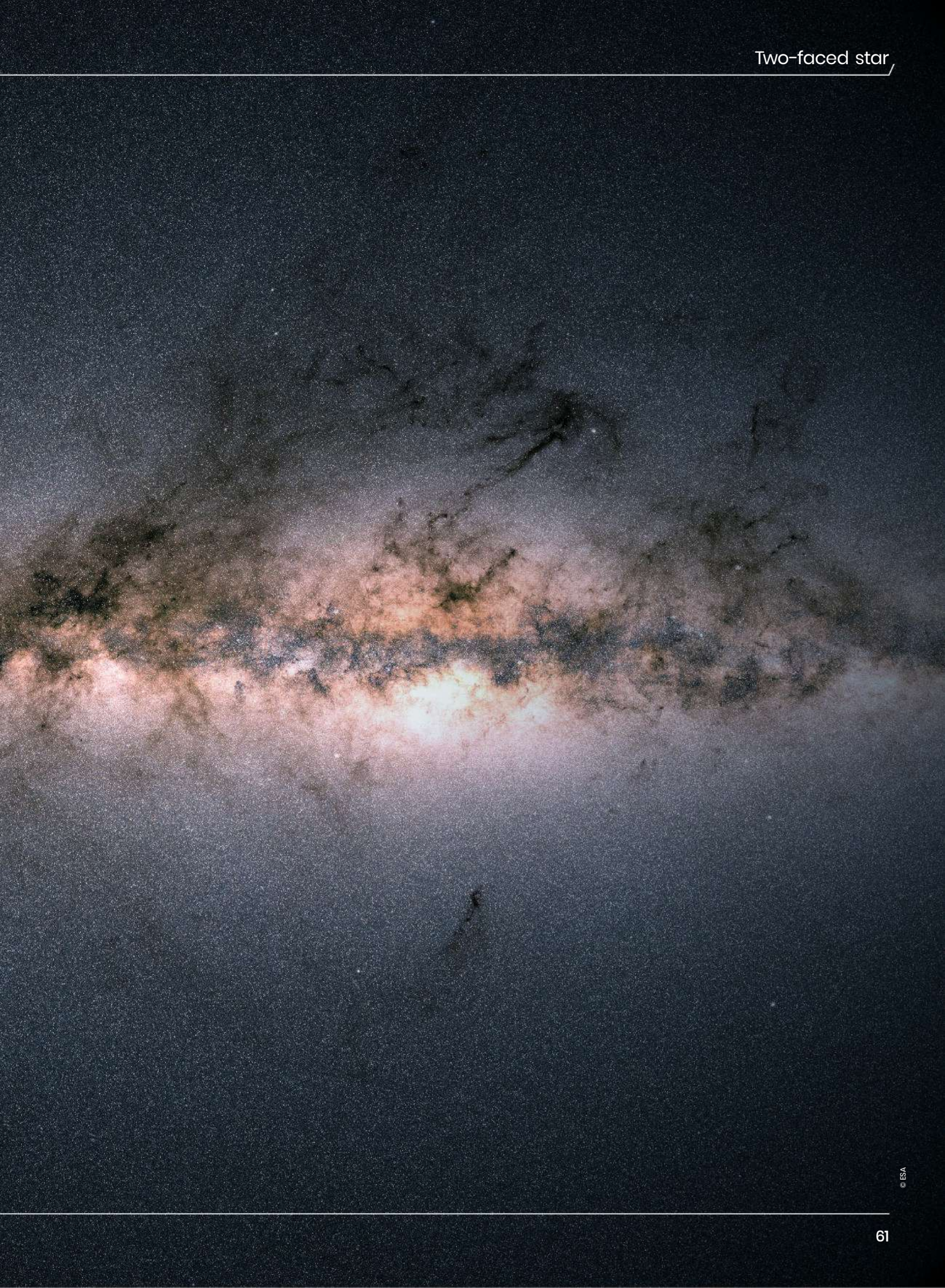
Reported by David Crookes

A white dwarf more than 1,300 light years away appears very different depending on which side you're looking at. Called Janus, this white dwarf has been baffling astronomers. On one side, observations indicate the dying star's surface is made up of hydrogen. The other side appears to be made up of helium. It's not an exact split right down the centre, but it has proven perplexing and compelling all the same.

As with many such discoveries, this one caught astronomers by surprise. It's taken so long to spot Janus because the technology to do so has only become available relatively recently. In this case, researchers were making use of the Zwicky Transient Facility (ZTF) at Palomar Observatory, close to San Diego, California, which was commissioned in 2018. They were looking for rapidly rotating and highly magnetised white dwarfs in the hope of finding remnants of double white dwarf mergers. "ZTF takes photographs of a large portion of the northern sky each night so that we can look for objects whose brightness changes with time," explains Jeremy Heyl of the University of British Columbia in Canada. "In the near future the Vera Rubin Observatory will be starting a similar but much deeper survey in the Southern Hemisphere, so we will have an even better idea of the changing night sky."

The Gaia mission – launched by the European Space Agency (ESA) in 2013 – has also enabled astronomers to get to this point. "The Gaia mission has measured the distances, colours and brightnesses of billions of stars in the Milky Way so that we can identify white dwarfs among all of the stars," Heyl continues. "Because ZTF measures the brightness of perhaps more than one billion stars and looking for periodicity is costly, the team focused on the white dwarfs."

When studying the data, Janus stood out. It seemed very different to conventional white dwarfs because



© ESA

JANUS BY NUMBERS

2
faces: one hydrogen, one helium

1,300
light years away in the constellation of Cygnus

2
It's named after the two-faced Roman god of transition

15
minutes: how often it rotates on its axis

35,000
Kelvin – the white dwarf's temperature

5
times the temperature of the Sun

350,000
white dwarfs have been discovered by the Gaia mission

1
white dwarf with two faces has been found

of its rapid changes in brightness. Notably, Janus – also known scientifically as ZTF J203349.8+322901.1 – spins once every 15 minutes. "This particular object, according to Gaia, is a massive white dwarf, and according to ZTF it's varying every 15 minutes, so it's rotating rapidly and variable," Heyl affirms. "There are hints that it might have a strong magnetic field and is a white dwarf merger remnant."

This find warranted further investigation, so the team made use of the Caltech HIgh-speed Multi-color camERA (CHIMERA) instrument located at the Hale Telescope, which is also at Palomar Observatory. It's a high-speed, two-colour, wide-field photometer. Used in combination with HiPERCAM – a portable, quintuple-beam optical imager on the world's largest telescope, the Gran Telescopio Canarias on the island of La Palma in Spain's Canary Islands – it was possible to gather significant additional data.

"The CHIMERA instrument and HiPERCAM measure the flux from the white dwarf with a rapid cadence," Heyl explains. "CHIMERA confirmed that Janus is varying every 15 minutes, while HiPERCAM measured the flux in a wide range of bands, yielding more information about the source. Once the period was confirmed, the spectroscopy from the W. M. Keck Observatory atop Mauna Kea in Hawaii gave us more information about the source, in particular its composition and whether it has a strong magnetic field. We found that the composition was apparently changing as the star rotates."

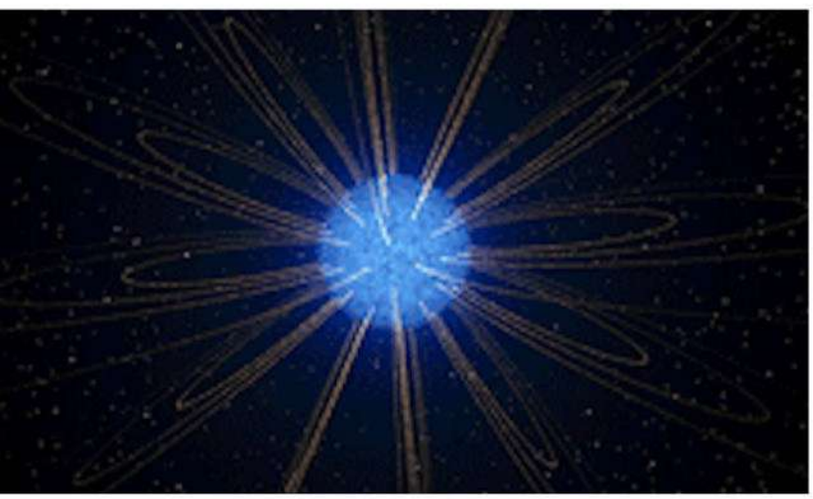
It was the observations made by the W. M. Keck Observatory which caused particular excitement to build among the astronomers. By using a spectrometer to spread the white dwarf's light into a rainbow of wavelengths, they could look at Janus' chemical fingerprints. This showed the two different elements on two sides of the star: helium and hydrogen. What's more, they were distinct. In other words, when helium was present, there were no signs of hydrogen, and vice versa.

Astronomers have been trying to nail down an explanation. "We mainly brainstormed potential models for the object. What does the object look like? What is the geometry and, finally, why is there hydrogen on one side and helium on the other?" Heyl says. After all, having helium and hydrogen isn't unusual because astronomers know that these elements are characteristic of white dwarf compositions. But having them so separated is intriguing.

"A white dwarf forms when a star up to eight times the mass of the Sun finally runs out of nuclear fuel," Heyl explains. "As it's running out of fuel, it's consuming hydrogen to produce helium and helium to produce carbon, oxygen and neon in a very thin layer. These fusing layers are very unstable, which drives nearly all of the hydrogen and helium from the surface of the star to form the white dwarf. Depending on how much hydrogen remains, the star can appear as a white dwarf with hydrogen lines (DA) or one with helium lines (DB)."

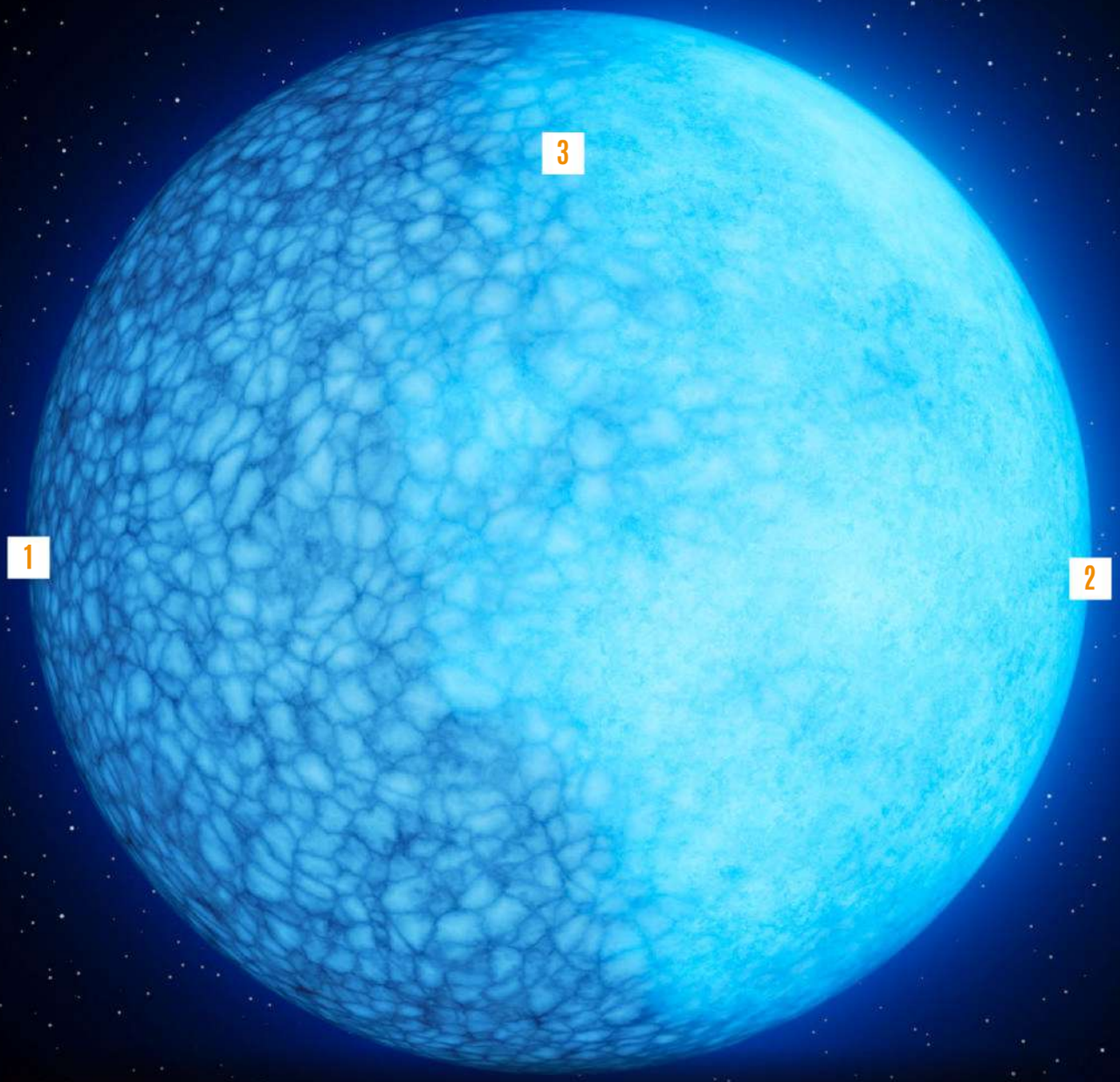
Crucially, helium is a heavier element, so it sinks to the bottom. Hydrogen, on the other hand, is a lighter element, so it floats to the top. When this happens, the surfaces of white dwarfs can transition from helium to hydrogen before returning to helium. Temperature plays a big part in when this happens. Janus was found to be 35,000 Kelvin, as determined by observations from NASA's Neils Gehrels Swift Observatory.

"If the layer of hydrogen is thin enough, then the white dwarf, when it's hotter than 40,000 Kelvin, might appear with helium



Janus is named after the two-faced Roman god of transition

Astronomers believe asymmetric magnetic fields are causing an uneven distribution of materials in the star



THE TWO SIDES OF JANUS

This white dwarf has a very curious trait

1 The helium side

The helium side looks bubbly because convection – the movement of particles through a substance – has taken place, destroying the thin hydrogen layer on the surface of Janus. It has allowed the abundance of helium to bubble up to the top.

2 The hydrogen side

The hydrogen side appears brighter and smoother. Here, the thin hydrogen layer remains intact because the magnetic fields may well be stronger on this side, preventing convection from taking place. The lighter hydrogen floats upwards.

3 The mysterious star

The entire white dwarf would look blue if you could get up close to it. It has a mass 20 per cent larger than that of our Sun, and because it rotates extremely fast on its axis, it looks as if it flashes in the night sky.

© Credit: K. Miller, Caltech/IPAC

WHAT'S THE LIKELY CAUSE OF JANUS' TWO FACES?

Two main theories have sought to explain why Janus has different sides

The atmospheric gases are changing

Asymmetric magnetic fields underpin both of the current theories. It's possible that magnetic fields on Janus are causing lower gas pressures in the white dwarf's atmosphere. This is determining how much helium or hydrogen is on the surface – where the magnetic field is strongest on one side of the star, a hydrogen ocean may form.

The elements aren't being allowed to mix

If the magnetic field is stronger on one side of the white dwarf than the other, then it may be limiting the amount of bubbling in the helium layer, which usually occurs when a star cools below 30,000 Kelvin. Preventing such convection stops helium from mixing and means there's an abundance of hydrogen on one side.

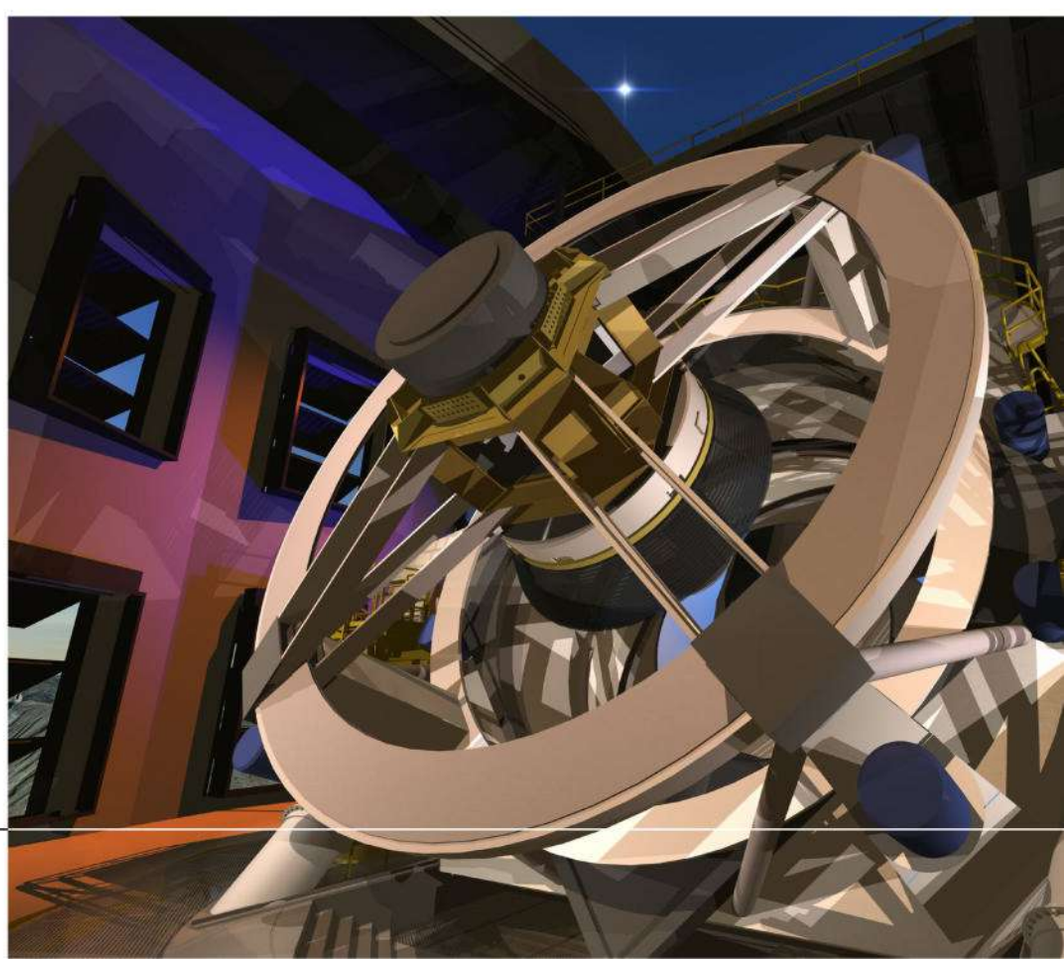
lines because the hydrogen hasn't yet floated to the top," Heyl continues. "From 40,000 Kelvin down to 30,000 Kelvin the hydrogen has floated to the top, so it looks like a hydrogen white dwarf. Below 30,000 Kelvin the surface layers of the star start a boiling motion called convection that mixes helium back into the hydrogen layer, diluting the hydrogen by a factor of 1,000 or so. At this stage, the white dwarf appears as a helium white dwarf again." Interestingly, Janus is at the right temperature for this boiling motion to start. "It should be making the transition from appearing as a hydrogen white dwarf to a helium one," Heyl says. "Something is interfering with this."

As such, the two sides are starkly separated. But why is this so? As it stands, there are a couple of models being proposed. Both of them involve a magnetic field and the possibility that the magnetic field is stronger on one side. "Hydrogen will accumulate where the magnetic field is strongest, so if there's a small amount of hydrogen on the star then it could gather in a hydrogen 'ocean' that covers half of the star," Heyl says, pointing to one of the model proposals.

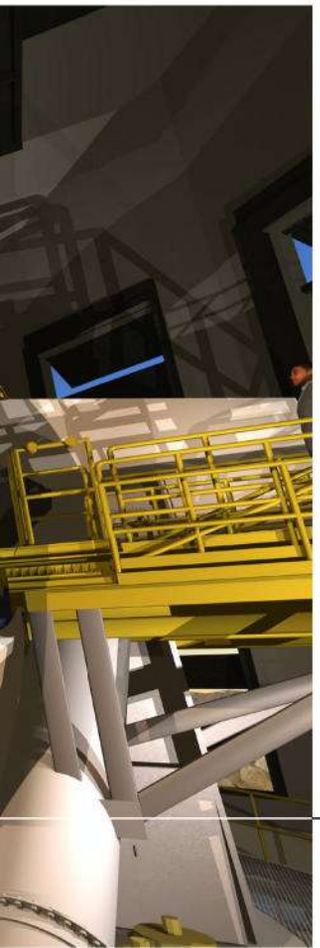
Alternatively, the asymmetric magnetic field could be playing a preventative role, stopping materials from mixing. "The magnetic field could be strong enough on one side of the star to prevent that gas from starting its boiling motion there, so helium doesn't mix in with the hydrogen on this side of the star," Heyl adds. "We see a similar process in the formation of sunspots on our Sun, where the strong magnetic field inhibits convection."

And yet there's a small problem. There's no direct evidence of Janus having a strong magnetic field, but that's not an insurmountable issue. "A field weaker than we can detect would be enough to make either of our two proposals happen, and we do see other white dwarfs where the magnetic field is significantly stronger on one side than the other." Even so, it would appear that the second theory – the one in which the magnetic field is preventing a mixing of material – is more likely. "It doesn't require a specific amount of hydrogen," Heyl explains. "The star also happens to be at a temperature where the convection is just starting, so even a weak magnetic field could affect that."

More research is clearly needed, and ZTF will continue to be used to search the sky for white dwarfs in the hope of discovering more stars just like Janus. Other facilities



> "There are hints that it might have a strong magnetic field and is a white dwarf merger remnant" **Jeremy Heyl**



A white dwarf is the burnt-out core of a dead star, typically made of hydrogen and helium

The LSST may uncover more white dwarfs like Janus, and scientists are hopeful it will allow them to make a breakthrough

will be used as well, such as the Vera C. Rubin Observatory in Chile, where the Large Synoptic Survey Telescope (LSST) is under construction. But while there is optimism, astronomers are also cautious. "We would expect to find a few more stars like Janus with LSST because we will be able to study many more white dwarfs with that survey," Heyl says. "However, these types of objects, which are obviously two-faced to us, are difficult to find because the geometry has to be just right for the star to show us one face, then the other."

That said, it's possible that similar white dwarfs have already been seen, but astronomers were just not aware they're of the same ilk. "There are also other white dwarfs where we see both hydrogen and helium lines, but in these stars the two elements both appear all of the time – perhaps they are also two-faced but we are looking from the wrong point of view to see the changes as the star rotates," Heyl adds.

Still, this is one mystery that should be resolved at some stage in the future, thanks to advancing technology. Indeed, the team which has been studying Janus is already considering a myriad of ways to find out more, since they're keen to figure out the workings of this particular white dwarf's internal dynamics. Cracking the mystery could also better our understanding of atmospheric physics. "For Janus in particular, it would be great to study the star with polarised light because the magnetic field causes the radiation in the spectral lines to be circular polarised," Heyl says. "We could then measure whether Janus has a weaker field than we can detect with the Keck spectroscopy that we have so far." The current research, published in the journal *Nature*, is only the start.

David Crookes
Science and technology journalist
David has been reporting on space, science and technology for many years, has contributed to many books and is a producer for BBC Radio 5 Live.

© ESA/Hubble; LSST Corporation

The Sun's magnetic field influences the Solar System

FOCUS ON

STARS WITH POWERFUL MAGNETIC FIELDS COULD NARROW THE SEARCH FOR ALIEN LIFE

Small stars with unexpectedly strong magnetic forces could be blasting their planets with radiation

Reported by Robert Lea

Astronomers have discovered evidence of small stars with shockingly strong magnetic fields that might not be ideal hosts for habitable worlds. New research suggests unexpectedly intense magnetic fields arise around cool, small stars when the surfaces and interiors of those stars start out by rotating at the same speed, but over time drift apart and spin out of sync. The team behind the study calls that internal mechanism core-envelope decoupling, a process that could ultimately impact our search for life. "Stars experiencing this enhanced magnetism are likely going to be battering their planets with high-energy radiation. This is predicted to last for billions of years on some stars, so it's important to understand what it might do to our ideas of habitability," Lyra Cao, an astronomy graduate student at Ohio State University, said.

That radiation could roast nearby planets, potentially boil away their liquid water, prevent complex molecules from forming and thus inhibit key ingredients for life. The findings are surprising because low-mass stars, such as the ones observed by the team, are common and expected to often host exoplanets. But rather than discourage the search for alien life, this work can suggest which systems are more likely to host habitable worlds. It can simply redirect the hunt. For mid-sized stars like the Sun, surface magnetism is linked to stellar spin, like a stellar dynamo. This means stellar spins can be used to assess physical properties of stars, such as their magnetic fields, and can reveal more about how stellar bodies interact with their environment, such as any surrounding exoplanets.

Until now, astrophysicists had assumed that the magnetism of stars with masses lower than the Sun's, which can rotate very rapidly or very slowly, worked in the same way. This prompted scientists to theorise that small stars likely had weak magnetic fields, suggesting these stars would be ideal hosts for habitable worlds. However, there was a caveat: there are examples in which this 'stellar-spin clock' appears to have stopped, Cao pointed out. As stars age, their rotation slows because they lose angular momentum – a process called 'spinning down'.

Cao and the research team think that as the star's core and its outer layer decouple in terms of spin speed and then sync back up, that could drive a type of magnetism seen around small stars that's strikingly different from that of the Sun. "We're finding evidence that there's a different kind of dynamo mechanism driving the magnetism of these stars," said Cao. "The next thing to do is verify that enhanced magnetism happens on a much larger scale. If we can understand what's going on in the interiors of these stars as they experience shear-enhanced magnetism, it's going to lead the science in a new direction."

© Getty Images

SPACE EXPLORATION

Why are most rockets white?

In fact, there are two questions here: why are most rockets white? Conversely, why are some rockets not white? A white outer colour is useful to minimise heat absorption into the body of the rocket. For rockets that use fuels at very low cryogenic temperatures, such as liquid hydrogen and liquid oxygen, even very small amounts of heat introduction can result in the liquid fuel 'boiling off' into gas and being lost. Europe's Ariane 5 rocket launches from French Guiana in South America, so reducing heat input to the rocket in that hot, tropical climate is important.

However, painting the surface of your rocket white adds weight to the rocket, which you want to be as light as possible, so you only do it when it brings real benefit. You can have rockets which are part white, part other colour, often the natural colour of the structure – orange for the thermal protection of the Space Shuttle fuel tank, for example. You can also decide not to paint the rocket at all – the Electron micro-launcher is all-black, the colour of the carbon fibre used in the structures.

Kate Underhill, rocket scientist at the European Space Agency

"A white outer colour is useful to minimise heat absorption into the body of the rocket"

An Ariane 5 lifting off from French Guiana

The Sun turns orange or pink near the horizon

Space debris is dangerous, as it can collide with functional craft and satellites

SOLAR SYSTEM

Why is light from the Sun white, yet looks yellow?

Earth's atmosphere protects us from the harsh environment of space, but it also alters the way we see objects beyond it. Atoms, molecules and other particles in the air absorb, scatter and refract any light passing through. When we look at the Sun on Earth, the shorter, bluer wavelengths of light are scattered by the atmosphere, only allowing the longer, redder wavelengths through, making it appear yellower. This is more pronounced the more atmosphere the light has to pass through, hence why the Sun is a deep orange-red at sunrise and sunset.

Even when viewed from space, however, light from the Sun isn't perfectly white. Rather than emitting an even amount of light across all colours, the Sun radiates different amounts of light at different wavelengths in a way that's characteristic of its temperature. The Sun shines brightest at green wavelengths, but has more light at the redder side of the visible spectrum than the blue. Recent simulations of stellar light and its perception by the human eye showed that if we were to view the Sun from space – dialling down the brightness so we wouldn't be blinded – it would have a very pale orange tone.

Belinda Nicholson, postdoctoral research assistant at the University of Oxford's Department of Physics

SPACE EXPLORATION

Who is responsible for falling space debris?

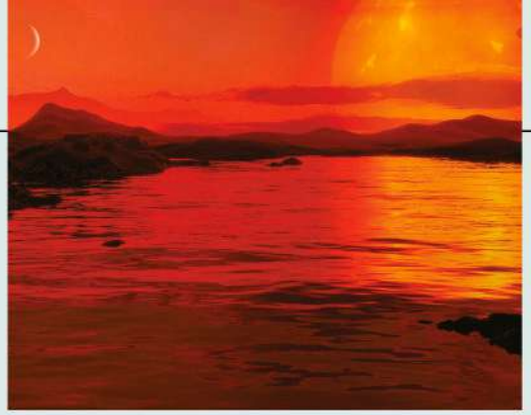
Space is an area beyond national jurisdiction. Like the high seas, space is governed through international law. The 1967 Outer Space Treaty and four other international space treaties that followed set out a framework and key principles to guide responsible behaviour. The 1972 Liability Convention specifies a compensation regime that would apply in many circumstances of damage caused by space debris falling to Earth, as well as when satellites collide in space.

This legal regime imposes liability on 'launching states' for damage caused by their space objects, which includes an absolute liability regime when they crash to Earth as debris. The liability under international space law is therefore imposed on countries, even where the space object or debris that causes the damage is privately owned and/or operated. The Liability Convention has only been previously invoked once – for the Cosmos 954 incident of 1978 – and therefore may not be regarded as a powerful disincentive. However, it is likely to come into play in the future in a more crowded space environment and with more uncontrolled re-entries. Of course, this legal framework applies only after the damage occurs.

In addition, there are other regulatory 'rules of the road' that deal with space governance agreed through the United Nations Committee on the Peaceful Uses of Outer Space, including practical guidelines for debris mitigation and long-term sustainability of space activities. In reality, a globally coordinated space traffic management system will also be vital to avoid collisions that would result in loss of control of satellites, leaving them to tumble helplessly in orbit or fall back to Earth.

Steven Freeland, emeritus professor at Western Sydney University, professorial fellow at Bond University and director of the International Institute of Space Law

© ESA/CNES/ARIANESPACE-Optique Photo Video du CSG, 2013 / NASA / ESA / Jesse Carpenter / Bill Moede / Getty



ASTROPHYSICS

Do all galaxies have a black hole at the centre?

It sure seems that way! The centre of every galaxy we've been able to examine in detail has proved to be the host of a supermassive black hole. The most famous recent addition to our understanding is the directly imaged shadow of the supermassive black hole in the centre of Messier 87. At 6 billion times the mass of our Sun, Messier 87's black hole is a tremendously large object. But what of other more distant galaxies, where we can't look directly? Messier 87 gives us another clue. In addition to being able to see the shadow of the black hole directly, its supermassive black hole also drives a thin jet of gas, larger than the entire galaxy, out from its centre. The energy required to launch material like this is best explained by a black hole, and in Messier 87 we see them together. In distant galaxies, we can use the presence of these energetic jets, or similar phenomena, to infer the frequent presence of a supermassive black hole – and they are indeed so frequent that we conclude that all massive galaxies should have one.

Jillian M. Scudder, associate professor in the department of physics and astronomy at Oberlin College and Conservatory

© NASA/R.Hurt/Caltech-JPL/Getty

EXOPLANETS

What is a Hycean planet?

Hycean planets are a class of planets bigger than Earth and smaller than Neptune with massive, planet-wide oceans and atmospheres made mostly of hydrogen. Astronomers have discovered thousands of exoplanets – planets outside the Solar System. The most common types of exoplanets discovered so far are unlike any planet in the Solar System, and are between the sizes of Earth and Neptune. It's not yet known what the interiors of these planets are made of, but one theory is that some of them could be rich in water, with massive oceans covering the surface. If such a planet is at the right temperature, the ocean could even be habitable for some types of life, for example some microbes.

Hycean planets are defined as having planet-wide oceans at temperatures which are habitable for some types of life. They also have puffy, hydrogen-rich atmospheres and can be up to 2.6 times larger than Earth, with atmospheric temperatures up to 200 degrees Celsius (392 degrees Fahrenheit). While there isn't yet enough data to unambiguously identify a Hycean planet, several known exoplanets have been classed as potential Hycean candidates based on their sizes, temperatures and parent stars. Observations with large telescopes in the near future will help to determine if these planets are indeed Hycean, and whether any of them could be harbouring life.

Anjali Piette, Carnegie Institution for Science

These water worlds could be common in the wider cosmos

NGC 3627 contains a bright X-ray source at its centre that is suggestive of a supermassive black hole

Artist's impression of a rogue planet

PLANETS

Can a planet exist without a star?

There are roughly 20 planets known that are free-floating and not orbiting any star, so the answer to this question is yes! Although maybe not entirely yes...

Most planets are thought to form in big discs around newly born stars called protoplanetary discs, and these planets get to live their life orbiting their parent star. However, as the planetary system is building itself up, the orbits of planets can be highly dynamic, which could lead to planets colliding – which is how we think Earth got its Moon – or even be ejected out of the system entirely. The interstellar object 'Oumuamua is thought to be such a planetary body that was flung out of its own stellar system, and is currently travelling through and outside our own Solar System. It's thought that there are many planets that share this same fate, and some astronomers have estimated that there are more of these 'free-floating' planets than there are stars in the Milky Way.

While most planets need a sun to be made, they don't need one to exist, and can be found outside of stellar systems. There are also the planets that live around dead stars, which give us insight into the Solar System's own future, and those thought to be made from the deaths of very large stars... but that's a topic for another time.

Christopher Manser, Imperial College research fellow at Imperial College London

ASTROPHYSICS

How do gravitational waves work?

Gravity isn't just a force that keeps things glued together. Through our understanding of general relativity, we know that gravity can make gravitational waves, or ripples in the fabric of space-time. Shortly after formulating his general theory of relativity, Albert Einstein realised that gravity can make waves. However, he quickly doubted his own conclusions. The realisation that gravitational waves exist came from a simplified form of general relativity, and Einstein didn't know if the waves were real or just an artefact of the simplification process. It took several decades before physicists came to the firm conclusion that general relativity does support gravitational waves. In other words, they are indeed a real thing.

Pretty much anything in the universe doing anything at all makes gravitational waves. All it takes is a little wiggling, which gravitational waves have in common with pretty much any other wave. If you wiggle around in water, you make water waves. If your voice box wiggles around, it makes sound waves. If you wiggle an electron, you make electromagnetic waves. To make a gravitational wave, all you need to do is make mass accelerate. These waves travel outwards from the source at the speed of light and are literal ripples in the force of gravity. When a gravitational wave passes through you, you get stretched and squeezed as if giant hands were playing with you like a piece of putty.

Paul Sutter, astrophysicist at SUNY Stony Brook and the Flatiron Institute in New York City

"Pretty much anything in the universe doing anything at all makes gravitational waves"

FOCUS ON

AN ANCIENT STAR THAT CRASHED A HOT, YOUNG STAR PARTY COULD SOLVE A SOLAR SYSTEM MYSTERY

Astronomers saw the old cosmic interloper in a region of star formation over 2,000 light years away

Reported by Robert Lea

Astronomers have discovered an ancient stellar body gatecrashing a gathering of hot, young stars. The interloper was found in a star-forming region located around 2,350 light years from Earth called NGC 2264. While such intruders have been observed before, the mixing of an old star and a grouping of young stars was unexpected. This is something scientists previously thought not to happen.

These findings may one day implicate our understanding of the journeys stars take across our universe and inform us on how stellar objects form dynamic relationships with their environments. Moreover, they may also have ramifications closer to home. The possibility of older interlopers in young star systems may explain how our Solar System, and particularly Earth, came to be enriched with certain isotopes of elements long ago.

"We were using the Gaia satellite to look for fast-moving stars that are ejected from star-forming regions due to encounters with other stars when we serendipitously found an interloping star," Richard Parker, an astrophysicist at the University of Sheffield and leader of the discovery team, said. "This star had formed elsewhere but was passing through this region. We noticed that its combination of colour and brightness meant that it was an evolved star known as an asymptotic giant branch (AGB) star."

AGB stars are formed when stars with masses around that of the Sun, or up to eight times greater, run out of hydrogen to convert to helium in their cores, but still continue the nuclear fusion process in their outer layers. The Sun will go through this stage of stellar evolution in around 5 billion years, forming a star similar to the cosmic gatecrasher the team found in NGC 2264. These 'retired' AGB stars are also believed to create large quantities of radioactively unstable chemical elements, namely aluminium-26 and iron-60, which they can release to their surroundings in stellar wind.

However, scientists estimate that when our Solar System was in its infancy, it was already enriched with these isotopes. Not only that, but it's also believed those elements were incorporated into the planets as they formed. In the case of Earth, for instance, aluminium-26 and iron-60 may have dominated the internal heating of our planet – thus these isotopes likely helped develop plate tectonics, which now assist in sustaining a breathable atmosphere over Earth. "This means that some process delivered aluminium-26 and iron-60 to our Solar System as it was forming," Parker said.

Elements like these are also released when massive stars much larger than the Sun explode at the ends of their lives, therefore distributing all the isotopes they had forged during their existence. These supernova explosions were previously believed to be responsible for the Solar System's early enrichment, but the caveat with this theory is that such massive stars would have also produced a great deal of radiation upon

detonation. In the vicinity of the infant Solar System, this might have heated gas, preventing it from clumping and forming the planets. "It was thought that the only plausible origin of these radioactive elements was from the supernovae of massive stars that formed in the same stellar groups as stars like our Sun," Parker said. "The discovery of an AGB star in a star-forming region throws the debate wide open on the origin of these chemical elements. If the aluminium-26 and iron-60 instead come from AGB stars, this then removes the problem of the massive stars' destructive radiation." Parker added that because groups of young stars like NGC 2264 tend to exist in relatively compact configurations, the team had considered the chances of finding an interloping old star among such a young stellar cluster to be quite low.

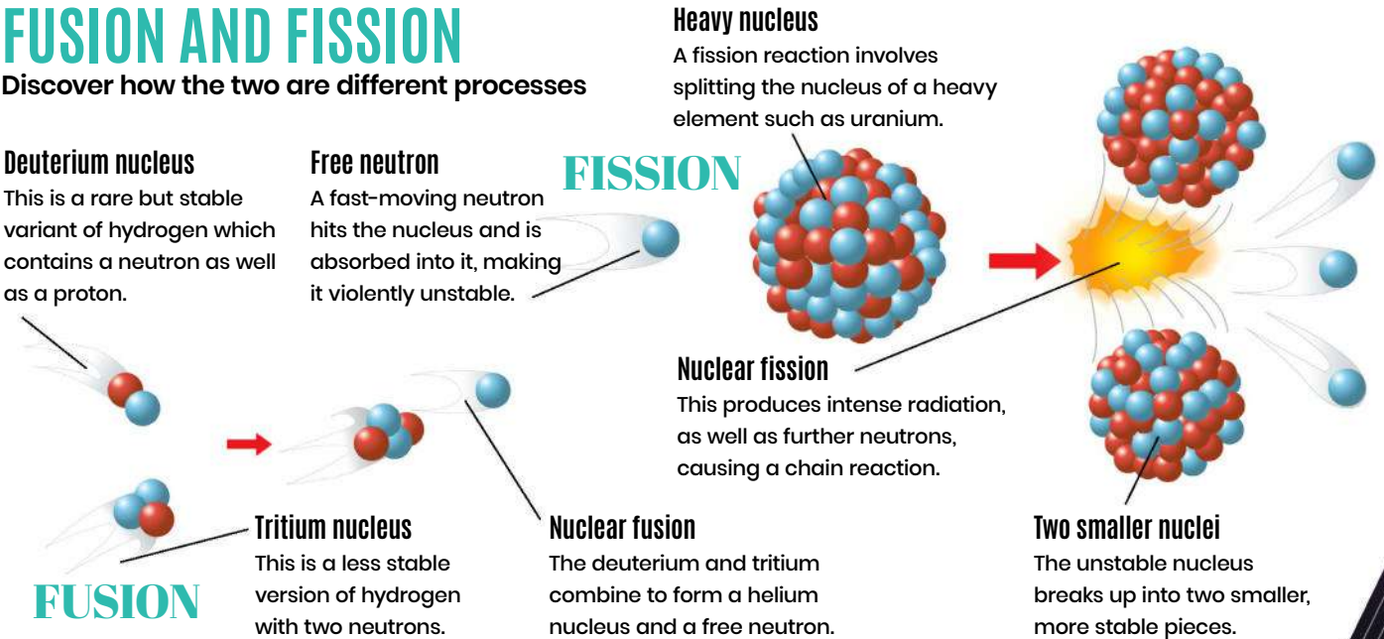
After spotting the AGB intruder in NGC 2264 using observations from Gaia Data Release 3, the scientists set out to discover if it was possible the aluminium-26 and iron-60 enrichment happened in the Solar System via passing AGB stars and their stellar winds rather than supernova explosions.

The team used computer simulations to calculate precisely how much of these chemical elements could be captured by our Solar System when it was forming. Sure enough, they found the amounts of these isotopes captured in the model appear consistent with measured levels in the Solar System. "Previous work conducted around 30 years ago suggested that the chances of the Sun encountering an AGB star were quite low," Parker said. "We haven't done anything to change that probability, but have shown that it can happen. I was surprised by the result, but I am very pleased to bring the AGB-enrichment idea back into the literature."

Parker and the team now intend to hunt the universe for more retired stars interloping in the domain of young stars to see how common this phenomenon is. "The Gaia instrument was crucial to finding these types of objects, but is an instrument that works in the visible-light regime," Parker said. "Young star-forming regions are easier to observe at infrared wavelengths, so an infrared version of Gaia – currently on the drawing board – would be wonderful."

FUSION AND FISSION

Discover how the two are different processes


Heavy nucleus
A fission reaction involves splitting the nucleus of a heavy element such as uranium.
Deuterium nucleus
This is a rare but stable variant of hydrogen which contains a neutron as well as a proton.
Free neutron
A fast-moving neutron hits the nucleus and is absorbed into it, making it violently unstable.
FISSION
Nuclear fission
This produces intense radiation, as well as further neutrons, causing a chain reaction.
FUSION
Tritium nucleus
This is a less stable version of hydrogen with two neutrons.
Nuclear fusion
The deuterium and tritium combine to form a helium nucleus and a free neutron.
Two smaller nuclei
The unstable nucleus breaks up into two smaller, more stable pieces.

© Getty

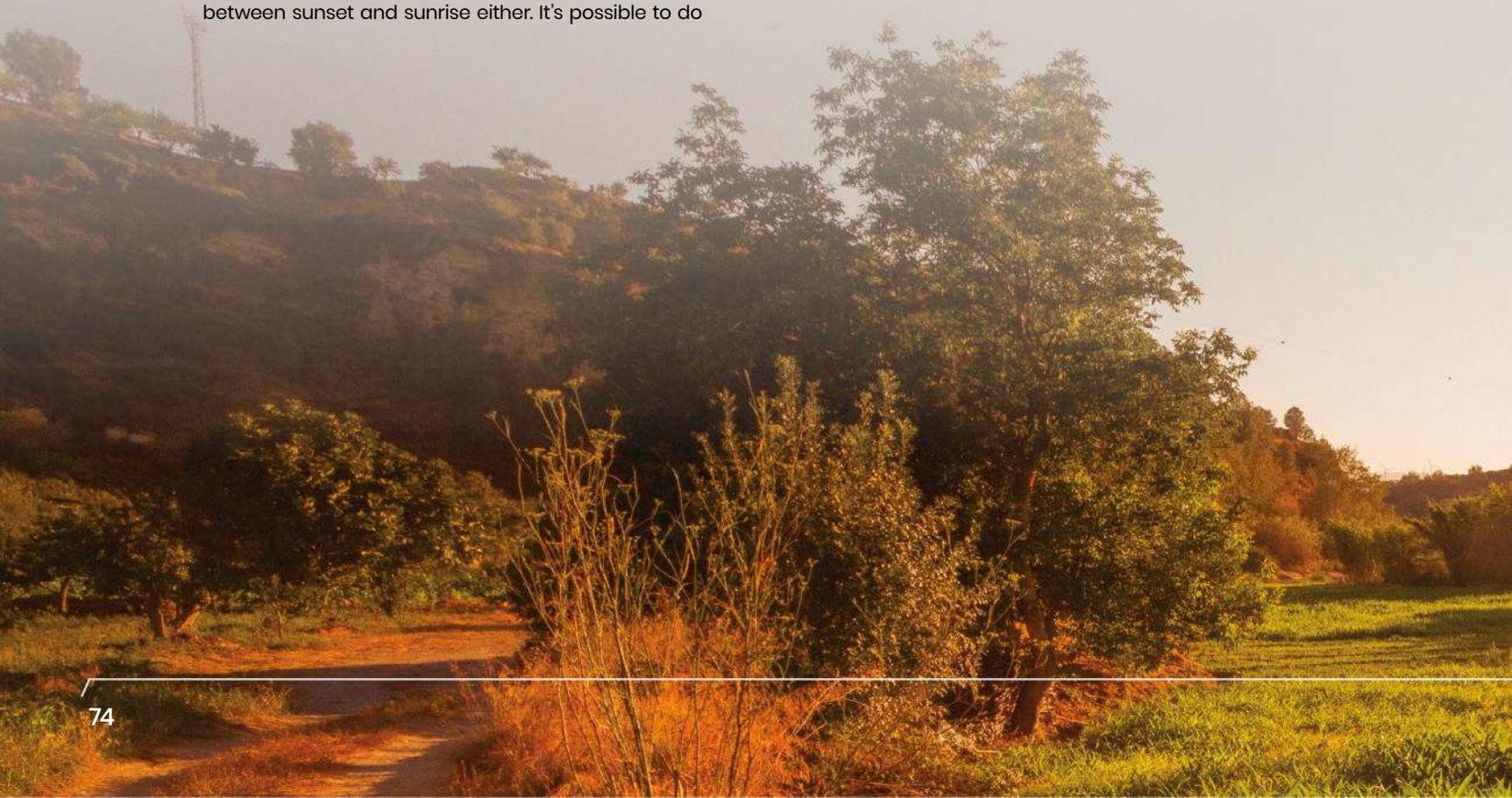
DAYTIME ASTRONOMY

Forget staying up late, All About Space shows you how to get stuck into observing without waiting until the small hours

Written by Stuart Atkinson

When most people think of astronomy, they picture someone standing outside on a sparkling clear night, gazing up at the wonders of the universe, perhaps using a telescope or binocular, or just sweeping the night sky with their eyes, taking in the view of stars, planets, the Milky Way and other natural nocturnal wonders. Indeed, a Google image search for 'astronomy' will bring up hundreds, even thousands, of pictures of people standing on their own, or in a small group, peering into telescopes beneath a star-dusted sky long after the rest of the world has gone to bed.

As the old joke goes, astronomy is the perfect hobby for three types of people: insomniacs, burglars and vampires. But astronomy doesn't have to be such an anti-social pastime, and it doesn't have to be done between sunset and sunrise either. It's possible to do astronomy in the daytime – in fact, it's a good idea for every stargazer and sky-watcher to know what there is to see in the daytime sky because those sparkling clear nights are few and far between, and when they eventually arrive our view of celestial phenomena and events is often spoiled because of light pollution.



Target #1

THE SUN

While it's our nearest star, the Sun can be a challenging target without the right equipment

The most obvious thing to look for and study in the daytime sky is the Sun. One of the very first things that someone getting into astronomy learns is that the bright white ball they have seen shining brightly in the sky above them all their lives is in fact a star – the closest star to the Earth. The night sky is full of distant suns, each tiny twinkling dot a star like our own. But not exactly like it. Some stars are bigger than our Sun, while some are smaller. Some are hotter, some are cooler. However, like all the stars in the night sky, our Sun is an enormous, hot ball of gas that keeps burning through the process of nuclear fusion, providing us here on Earth with the light, heat and energy we need to survive. And because the Sun is a star, when you look at it you are definitely doing astronomy.

The good news for anyone wanting to observe the Sun is that it's much closer than almost every other astronomical object. Just 146 million kilometres (90 million miles) away, it's nearer to Earth than everything except the Moon and a couple of Earth's sister planets. Its close proximity means we are able to see and study it in great detail from here on Earth – but only if we use the right equipment. The Sun is incredibly bright, and it's so bright because it's so hot: on its surface the temperature is a stunning 6,000 degrees Celsius (10,832 degrees Fahrenheit), and its core is even hotter. That means anyone wanting to observe the Sun has to take extraordinary care and use special equipment and techniques, or else they risk serious eye injury or even permanent blindness. However, with the right gear and a healthy amount of caution and common sense, our closest star can be a fascinating object to study before the more distant stars come out.

Solar projection is a great way to view sunspots and solar eclipses

"The good news for anyone wanting to observe the Sun is that it's closer than almost every other astronomical object"

Target #2

THE PLANETS

It's sometimes possible to see planets in the daytime sky, but only if you have very good eyesight, you know exactly where to look for them and at what time of day, if they are well away from the Sun and the sky is very clear with no distracting clouds. The planet most easily seen in the daytime sky is Venus, because it's the brightest. When it's at its farthest point from the Sun, keen-eyed people can sometimes pick Venus out from the blue sky as a spark of silvery light. Others need binoculars to find it. Be careful, though, as you should never look for it, or any other planet, without hiding the Sun behind a building or hill so you don't accidentally look at it while planet hunting.

VIEW SUNSPOTS THE EASY WAY

1 Select a piece of white paper or card to use as a screen – make sure it's very clean, without any patterns or blemishes.

2 Cover up one of the objective (front) lenses of the binocular so only one image will be projected instead of two.

3 Position your screen behind the binocular.

4 Align your binocular with the Sun by holding it towards it and moving it around until a bright circle appears on the screen. Do not look through the binocular at any time.

5 Sharpen the Sun's image by turning the focusing wheel on the binocular.

6 Adjust the size of the projected image of the Sun by moving the binocular and screen apart.

7 If there is any sunspot activity on the Sun you will see the sunspots as small, dark markings on the bright solar disc.

8 If you can view the sunspots for several days in a row you will be able to see them change shape and size as they are carried across the Sun's face by the rotation of the Sun.

9 Even if there are no sunspots visible on the Sun when you look, check for any large sunspot groups just coming into view on the edge of the Sun. They will be better placed for viewing on subsequent days.

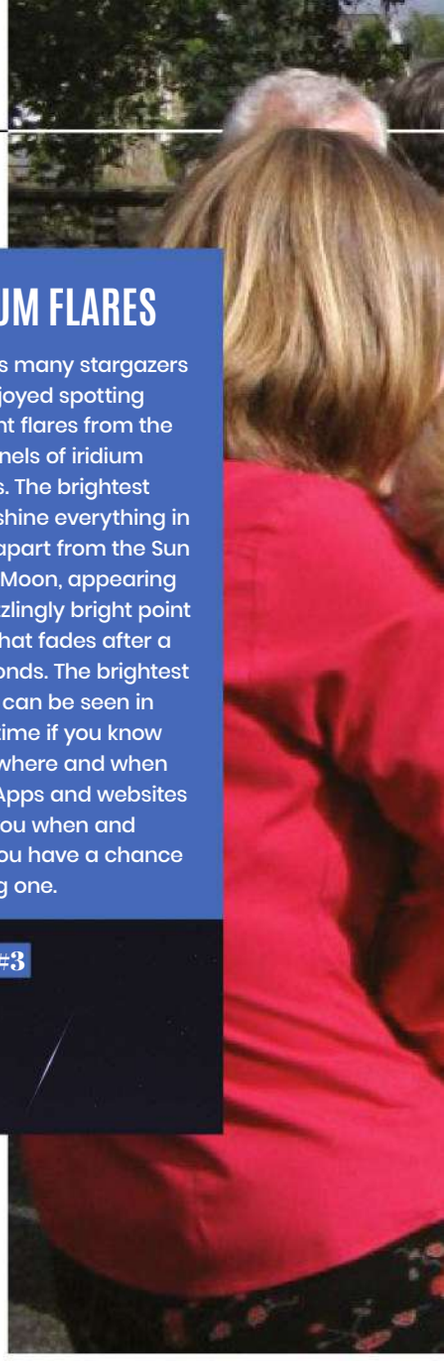
One simple and safe way of observing the Sun is to simply look at how its shape and colour changes through the day, depending on how much cloud it's shining through, how high it is in the sky and so on. When the Sun is high in the sky, or overhead, it's an eye-wateringly bright object. When the Sun is about to set, or has just risen, and is low in the sky it can appear bigger, bloated and more orange in colour than when overhead. This is because we're looking at it through more of the atmosphere, so its light is refracted and distorted, making it appear squashed, bloodshot and a lot less bright. But even when it's low and dim you still have to be very careful not to look directly at it for more than a moment, or you'll risk damage to your eyes.

Because it has always looked like a bright, blank, white disc in the sky, newcomers to astronomy are often amazed to learn that there are fascinating features to be seen on the face of the Sun. However, to see dramatic solar features such as sunspots, prominences and flares you have to find a way to magnify the Sun's disc, which is surprisingly small. It's easy to magnify the Moon or objects in the night sky – all you have to do is look at them through a binocular or telescope. But if you use those instruments on the Sun you will concentrate its light and heat into intense beams that will cook your eyes like fried eggs. However, with the right equipment and techniques it's possible to enjoy stunning views of the Sun perfectly safely.

The easiest way is to use solar projection. This involves – as the name suggests – projecting an image of the Sun onto a suitable surface and studying that image instead of looking directly at the Sun itself. To project a solar image you will need either a binocular or a small telescope and a piece of white paper or card to place behind them to use as a screen. By carefully positioning the binocular or telescope between the Sun and the screen at just the right angle, so the Sun's rays go straight through their lenses and form an image on the screen, you will produce an image of the Sun large enough to show any dark sunspots on its face at that time. Sometimes the Sun is completely blank, so don't worry if you can't see anything the first time you look. You can change the size and sharpness of the image by moving the screen closer to or further away, and by focusing your instrument in the usual way.

Using projection, you can watch sunspots as they appear from around the limb then follow them as they track across the disc, changing shape and size. The advantages of using solar projection to observe the Sun are many. It's very simple, very quick and cheap, too. It also means several people can see the Sun at the same time. However, it is absolutely vital you don't look through the projecting equipment or let your skin or anything else wander into the path of the light. Remember that you can burn paper with the Sun and a magnifying glass. Solar projection works on the same principle, so be very, very careful when viewing the Sun using this method.

It might seem pretty obvious that if you want a more detailed view of the Sun you will need to magnify it more – but how, if looking directly at the Sun through a telescope is dangerous? The solution is to fit your telescope with a special filter that



IRIDIUM FLARES

For years many stargazers have enjoyed spotting the bright flares from the solar panels of iridium satellites. The brightest can outshine everything in the sky apart from the Sun and the Moon, appearing as a dazzlingly bright point of light that fades after a few seconds. The brightest of these can be seen in the daytime if you know exactly where and when to look. Apps and websites will tell you when and where you have a chance of seeing one.

reduces its brightness to a fraction of a percent of its usual brightness. Using a solar filter, you can use your telescope and eyepieces to zoom in on its surface features just as you would zoom in on lunar craters, star clusters or the planets.

The most common and popular type of solar filter is a Mylar filter. Mylar is a very special material that looks deceptively like silver kitchen foil or the material helium balloons are made of, but is in fact a very dense, very lightweight specialised material astronomers have been using for decades now. You can either buy a ready-made Mylar filter produced specifically for your telescope make, model and size, or you can send off for a small sheet of the material and then make your own filter using a hoop of strong cardboard that pushes over the front of your telescope. There are lots of

WATCH THE SUN LIVE

1 Go onto the Solar Dynamics Observatory website: **sdo.gsfc.nasa.gov**.

2 Select the menu bar at the top right.

3 Select 'Data' from the menu.

4 Select 'The Sun Now' from the drop-down menu.

5 When 'The Sun Now' is highlighted in blue, scroll down the page to view images of the Sun taken at different wavelengths.

6 First select the view of the Sun in Hydrogen-alpha by selecting the image labelled 'AIA 304'. This will allow you to see any prominences on the edge of the Sun. The Sun's disc will appear a deep-red or deep-orange colour.

7 If you see any crimson loops, arches or feathery towers suspended above the limb of the Sun, these are prominences. Zoom in on them to see more details.

8 Look out for any bright spots or squiggles on the Sun's face. These might be powerful solar flares.

9 To see the Sun in 'white light', scroll down to the views labelled 'HMI Intensitygram'. There are three different ones. All show the view you would have of the Sun if you were projecting its image. These images of the Sun appear gold, yellow and white. The colours don't really matter. These views will allow you to see any sunspot activity on the Sun at that time. They will look like small, dark spots.

10 Zoom in on any sunspots visible so you can see their structure more clearly. Look out for the very dark centre 'umbra' region and the lighter streaked 'penumbra' that surrounds it.

© Christos Doudoulakis

SOLAR AND LUNAR SPACE STATION TRANSITS

Spotting the International Space Station (ISS) is now a very popular part of amateur astronomy – and many of you reading this would be thrilled at the sight of the ISS sailing silently across the sky, shining like a bright star. On very rare occasions the ISS' path across the sky takes it between us and the Moon or the Sun, and for a couple of seconds it can be seen silhouetted against it. To catch one of these transits you have to be in exactly the right place at exactly the right time, as predicted by phone apps or websites. You also need a telescope to be able to see the tiny silhouette of the ISS, fitted with a solar filter, of course, if it's transiting the Sun.

"Solar filters are safe as long as they are made of the correct material, fitted properly and are not suffering from wear and tear"

NAKED-EYE SOLAR EFFECTS

Sun dogs

Sun dogs, known scientifically as 'parhelia', look like miniature rainbows on either side of the Sun when it's low in the sky, either just before it sets or just after it has risen. They are caused by the Sun's light being refracted and reflected by ice crystals in the upper atmosphere, between five and ten kilometres (three and six miles) above Earth's surface.

Solar halo

All solar halos have a radius of 22 degrees. Solar halos are usually seen when the Sun is high in the sky and are caused by ice crystals high in the atmosphere refracting and bending the Sun's light. The most dramatic halos are very eye-catching, taking the form of a beautiful blue-white ring around the Sun, and can even be rainbow-hued.

Sun pillar

If plate-shaped ice crystals in the upper atmosphere line up in a certain way a column of silvery-blue or sometimes golden light can appear above the Sun, but only when it is at a low altitude, not when it is high in the sky. This is known as a 'Sun pillar', for obvious reasons, and they often linger in the sky after the Sun has set or herald its appearance before it has actually risen.

Circumzenithal arc

Occasionally, what looks like an upside-down rainbow can be seen high above the Sun, almost overhead. This is a circumzenithal arc – a curve of rainbow-coloured light which, as the name suggests, is the brightest segment of a ring centred on the zenith, the overhead point in the sky.

solar filter-making guides available online, or from your local astronomical society.

Using a Mylar solar filter means you can magnify the Sun dozens or even hundreds of times, allowing you to see some very fine detail within and around sunspots and see how they change shape over time, with areas appearing and disappearing, different small groups of spots joining up to make larger groups and more. You will also be able to see the 'granulation' of the Sun's surface, which many people think looks like the outer peel of an orange seen through a magnifying glass.

Solar filters are safe as long as they are made of the correct material – be very careful not to buy cheap filters online, which may be made from material that will not protect your eyes – fitted properly and are not suffering from wear and tear. Any holes or scratches could let sunlight into your eyes and damage them. The main drawbacks of solar filters are their expense compared to simply using projection, and the way that they only allow one person to view the Sun at a time.

There are more than just dark sunspots on the Sun's surface, but if you want to see the spectacular loops and arches of fiery gas known as prominences and glimpse bright solar flares, you'll need to dig deeper into your pockets. If you want to see everything the Sun has to offer you will need to invest in, or borrow, a special solar telescope. These instruments are very specialised pieces of equipment featuring built-in filters which are tuned specifically to the 'Hydrogen-alpha' wavelength. Viewed in H-alpha, the face of the Sun is transformed from a blank, featureless disc to a sunspot-spattered cauldron. If there are any present at the time of viewing, prominences will look like fiery arches, loops or hoops on the Sun's edge, and should you see a brief flash or flaring of pink or white on the disc you'll have been lucky enough to witness a rare and powerful solar flare just as it happened.

Solar telescopes offer stunning, detailed views of our nearest star, but they are very expensive, and many people find them difficult to get to grips with. An alternative would be to buy a Hydrogen-alpha filter to go over the front of your telescope, but these are very expensive too.

If you want to see this kind of detail on the Sun but can't afford or don't have access to any of the equipment detailed above, don't worry! There are many free apps available for your smartphone or tablet, and websites you can visit which show 'live' views of the Sun in optical and other wavelengths. You can use them to see how spotty the Sun is and watch prominences leap off the Sun and fall back down again.

LUNAR-PLANETARY OCCULTATIONS

Very rarely, it's possible to see a planet disappearing behind – or emerging from behind – the curved limb of the Moon. Just like ISS transits, you have to be in the right place at the right time to see one of these planetary occultations, and will also need either a binocular or a telescope to see it. If you have patience and time things just right, the view, and the experience, can be truly amazing.

© Gehim; Anita Gould; Christos Doudoulakis; Erik Axdahl Axda0002

WHAT'S IN THE SKY?

What to look out for during this observing period

In this issue...

80 What's in the sky? Perfect your set-up and get the best views with our handy stargazing guides

82 Planetarium Where you can find the planets this month and the phases of the Moon

84 Month's planets Venus dominates the morning sky for early risers alongside Mercury

86 Moon tour How to find one of the most striking but overlooked craters on the lunar surface

87 Naked eye and binocular targets Find galaxies, beautiful star clusters and a demonic star on crisp autumn nights

88 Deep sky challenge Among the richest for deep-sky observers, September brings star clusters, nebulae and galaxies galore

90 The Northern Hemisphere Now into autumn, the darkened skies bring some astronomical favourites

92 Review We put the Vaonis Vespera Observation Station to the test

96 In the shops Our pick of the best gifts and accessories for astronomy and space fans

9 SEPTEMBER
The September Epsilon Perseid meteor shower reaches its peak

18 SEPTEMBER
Venus will reach its greatest brightness, dazzling at -4.5 in the dawn sky

19 SEPTEMBER
Neptune is at opposition in Pisces, glowing at magnitude +7.8

22 SEPTEMBER
Mercury will reach half phase, also known as dichotomy

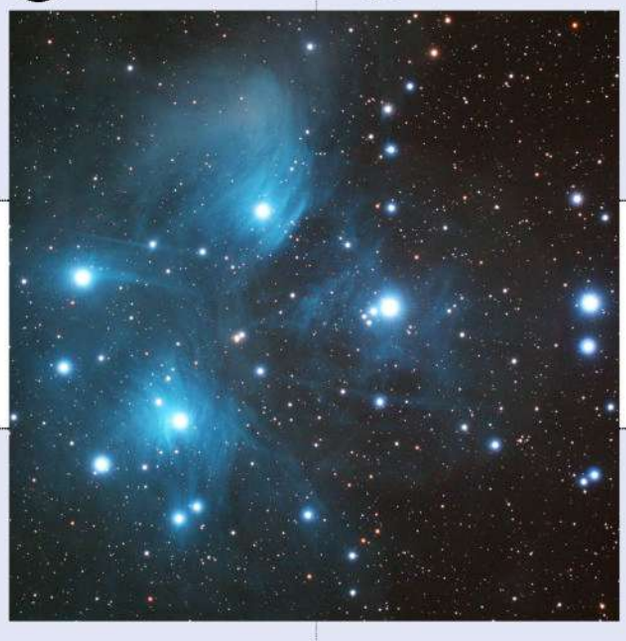
22 SEPTEMBER
Mercury is at its greatest elongation west in the morning sky, dazzling at magnitude -0.5

23 SEPTEMBER
September equinox

23 SEPTEMBER
Mercury is at its highest altitude in the morning sky, dazzling at magnitude -0.5

27 SEPTEMBER
The Moon and Saturn make a close approach, passing within 2°25' of each other in Aquarius

2 OCTOBER
The Moon and Jupiter make a close approach, passing within 3°08' of each other in Aries



2 OCTOBER
Asteroid 29 Amphitrite reaches opposition in Pisces, glowing at magnitude +8.8

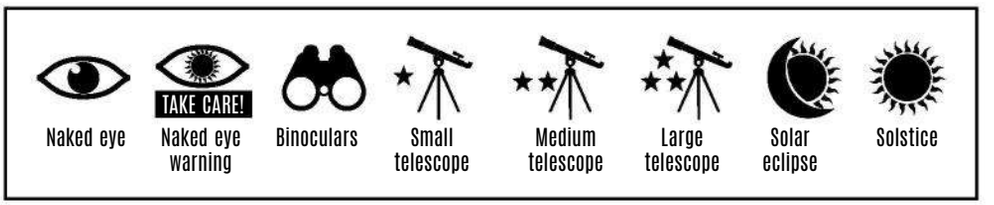
2 OCTOBER
The Andromeda Galaxy (Messier 31) is well placed for observation in Andromeda

3 OCTOBER
The Moon and Messier 45 make a close approach, passing within 59.5' of each other in Taurus

"Venus will reach its greatest brightness, dazzling at -4.5 in the dawn sky"

Red-light friendly

In order to preserve your night vision, you should read our observing guide under red light



Jargon buster

Conjunction
An alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Declination (Dec)
How high an object will rise in the sky. Like Earth's latitude, Dec measures north and south in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and 60 arcminutes in a degree.

Opposition
When a celestial body is in line with Earth and the Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

Right Ascension (RA)
RA is to the sky what longitude is to Earth, corresponding to east and west. It's measured in hours, minutes and seconds, as since Earth rotates on its axis we see different parts of the sky throughout the night.

Magnitude
An object's magnitude tells you how bright it appears from Earth, represented on a numbered scale. The lower the number, the brighter the object. A magnitude of -1.0 is brighter than +2.0.

Greatest elongation
When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongation and as morning stars during western elongation.

© Getty

MOON CALENDAR

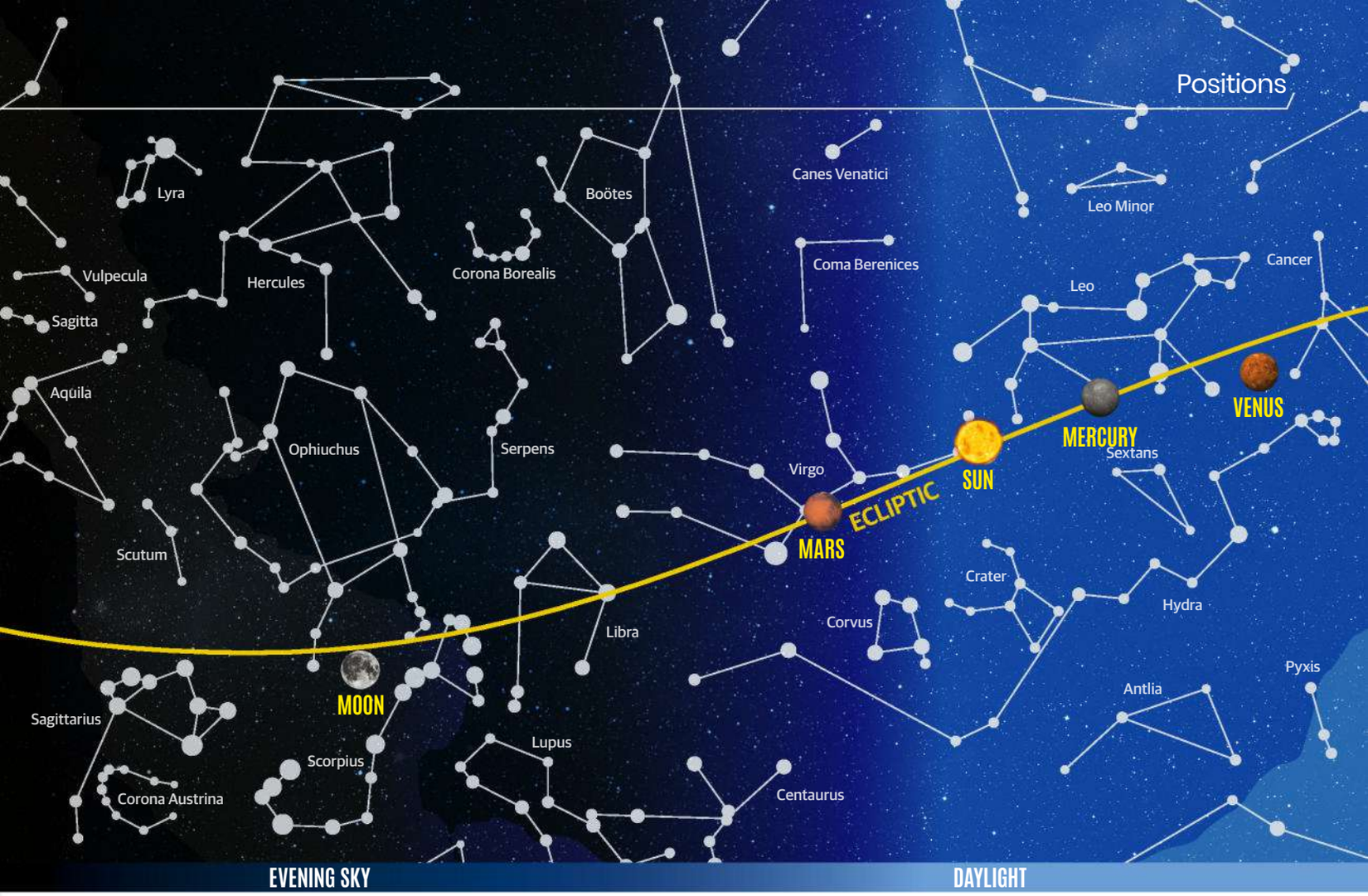
* The Moon does not pass the meridian on 28 September

8 SEP 36.7% 17:04 23:42	9 SEP 27.3% 17:49 --:--	10 SEP 19.0% 00:45 18:21	11 SEP 11.9% 01:55 18:44	12 SEP 6.4% 03:08 19:01	13 SEP 2.5% 04:20 19:14	14 SEP 0.4% 05:32 19:26
15 SEP NM 0.2% 06:43 19:36	16 SEP 2.0% 07:53 19:46	17 SEP 5.8% 09:05 19:57	18 SEP 11.4% 10:19 20:09	19 SEP 18.9% 11:36 20:25	20 SEP 27.9% 12:55 20:47	21 SEP 38.2% 14:15 21:19
22 SEP FQ 49.3% 15:29 22:05	23 SEP 60.9% 16:31 23:11	24 SEP 72.2% 17:16 --:--	25 SEP 82.4% 00:33 17:47	26 SEP 90.8% 02:04 18:10	27 SEP 96.7% 03:38 18:27	28 SEP --.-%* 05:11 18:41
29 SEP FM 99.7% 06:41 18:54	30 SEP 99.5% 08:10 19:08	1 OCT 96.3% 09:39 19:24	2 OCT 90.5% 11:07 19:43	3 OCT 82.7% 12:32 20:09	4 OCT 73.6% 13:50 20:45	5 OCT TQ 63.7% 14:56 21:32
6 OCT 53.4% 15:47 22:33						

% Illumination
Moonrise time
Moonset time

FM Full Moon
NM New Moon
FQ First quarter
TQ Third quarter

All figures are given for 00h at midnight (local times for London, UK)



ILLUMINATION PERCENTAGE

PLANET POSITIONS

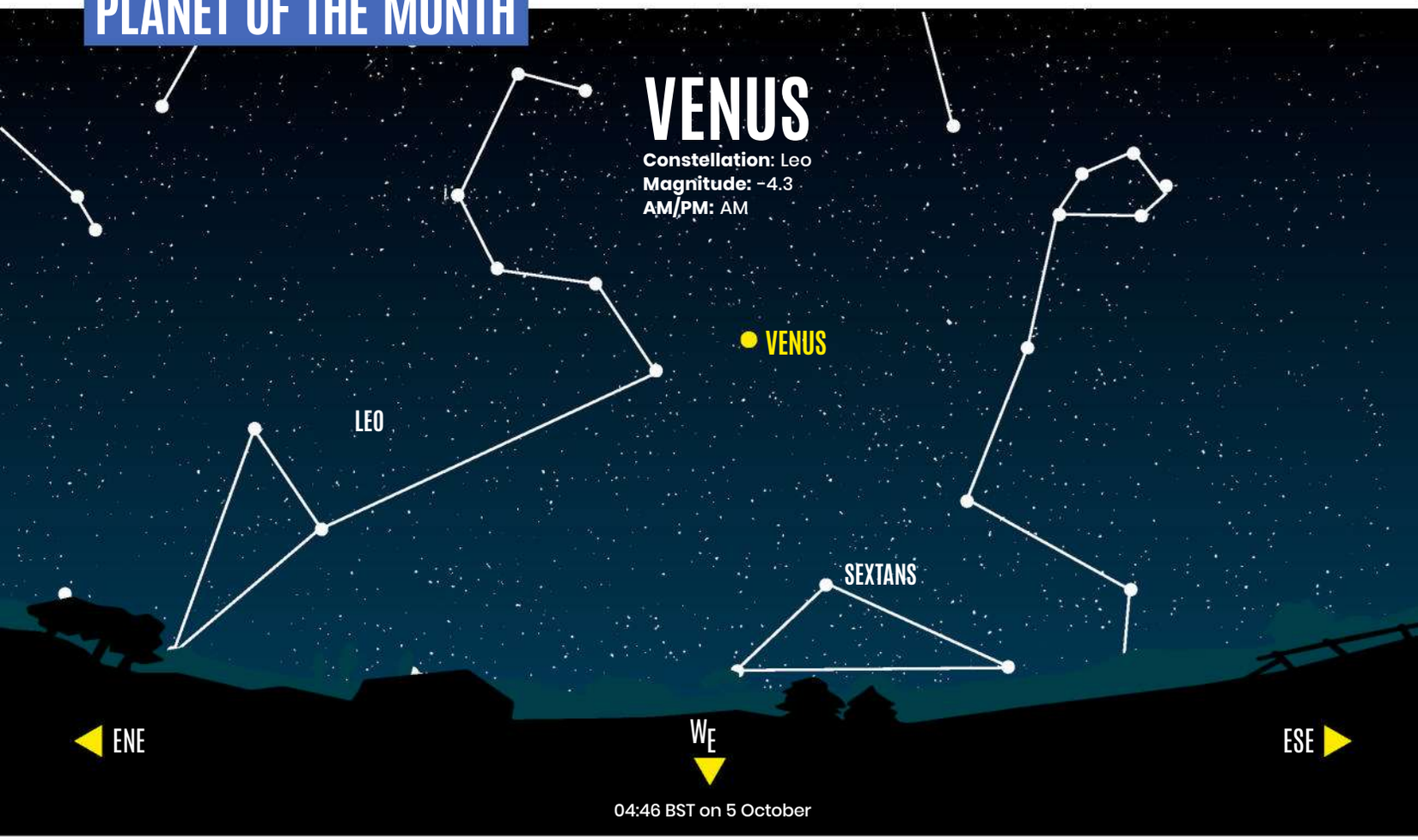
All rise and set times are given in BST

DATE	RA	DEC	CONSTELLATION	MAG	RISE	SET
8 SEP	10h 47m 47s	+03° 58' 56"	Sextans	+5.1	06:16	19:04
15 SEP	10h 35m 46s	+07° 31' 25"	Leo	+1.5	05:18	18:43
22 SEP	10h 49m 25s	+08° 15' 40"	Leo	-0.4	05:00	18:33
29 SEP	11h 24m 24s	+05° 43' 14"	Leo	-1.0	05:21	18:27
6 OCT	12h 08m 11s	+01° 09' 28"	Virgo	-1.2	06:04	18:19
8 SEP	08h 51m 11s	+10° 55' 27"	Cancer	-4.5	03:43	17:44
15 SEP	08h 59m 43s	+11° 25' 34"	Cancer	-4.5	03:21	17:28
22 SEP	09h 13m 55s	+11° 30' 26"	Cancer	-4.5	03:07	17:15
29 SEP	09h 32m 26s	+11° 08' 33"	Leo	-4.5	03:00	17:04
6 OCT	09h 54m 11s	+10° 19' 35"	Leo	-4.5	02:59	16:54
8 SEP	12h 26m 47s	-02° 16' 10"	Virgo	+1.7	08:26	20:11
15 SEP	12h 43m 29s	-04° 07' 19"	Virgo	+1.7	08:25	19:51
22 SEP	13h 00m 25s	-05° 57' 53"	Virgo	+1.7	08:24	19:30
29 SEP	13h 17m 35s	-07° 47' 11"	Virgo	+1.7	08:23	19:11
6 OCT	13h 35m 03s	-09° 34' 36"	Virgo	+1.6	08:22	18:51
8 SEP	02h 52m 41s	+15° 07' 17"	Aries	-2.7	21:22	12:10
15 SEP	02h 52m 04s	+15° 03' 15"	Aries	-2.7	20:54	11:42
22 SEP	02h 50m 48s	+14° 56' 29"	Aries	-2.8	20:26	11:12
29 SEP	02h 48m 56s	+14° 47' 07"	Aries	-2.8	19:58	10:42
6 OCT	02h 46m 30s	+14° 35' 23"	Aries	-2.8	19:29	10:11
8 SEP	22h 21m 01s	-12° 12' 15"	Aquarius	+0.5	19:15	05:15
15 SEP	22h 19m 07s	-12° 23' 08"	Aquarius	+0.5	18:43	04:41
22 SEP	22h 17m 20s	-12° 33' 03"	Aquarius	+0.5	18:14	04:11
29 SEP	22h 15m 44s	-12° 41' 46"	Aquarius	+0.5	17:46	03:41
6 OCT	22h 14m 21s	-12° 49' 05"	Aquarius	+0.6	17:18	03:11

THIS MONTH'S PLANETS

Venus dominates the morning sky for early risers alongside Mercury

PLANET OF THE MONTH

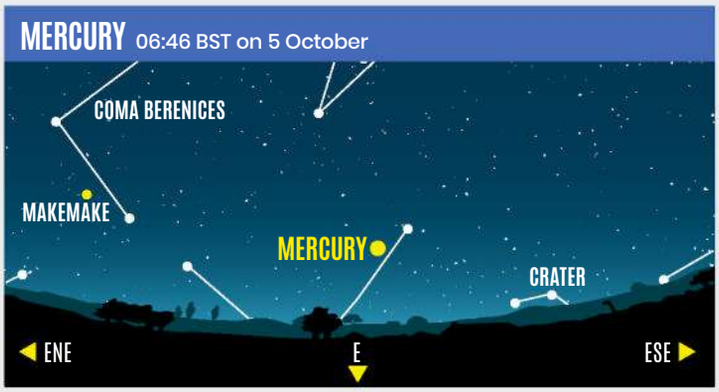


This month Venus will be strikingly bright to the naked eye, a dazzling 'morning star' in the east that will drag your eye away from everything else above the horizon. At the start of our observing period it will shine with a magnitude of -4.0, making it far brighter than everything else in the sky apart from the Sun and Moon. It rises a good two-and-a-half hours before the Sun, and as September ends and October begins it will drift eastwards into neighbouring Leo, where it will rise four hours before the Sun. By 5 October Venus will be shining very close to the star Regulus, which is one of the brightest stars in the sky – the 21st brightest, in fact – but is completely overwhelmed by Venus' glow. But before that Venus will have a close encounter with another body. Look out for a beautiful waning crescent Moon approaching and then passing Venus in the morning sky between 11 and 13 September.

Venus has always been in Mars' shadow as far as missions have been concerned. While a veritable armada of orbiters, landers and rovers has been sent to Mars over the years, Venus has only had infrequent visitors, many of which only whooshed past on their way somewhere else. But now, after being rather ignored for many years, Venus is being targeted by planetary scientists again. The somewhat-controversial announcement of the discovery of the gas phosphine in Venus' atmosphere a couple of years ago, which could be a sign of life there, has galvanised many astrobiologists, and there are now plans to return to Venus with probes and instruments to actively look for life in its clouds. NASA's planned missions might not reach Venus because of budget problems, but the private Venus Life Finder mission, based at the Massachusetts Institute of Technology and flown by Rocket Lab, could reach Venus around 2025.

> "By 5 October Venus will be shining very close to the star Regulus, which is one of the brightest stars in the sky"

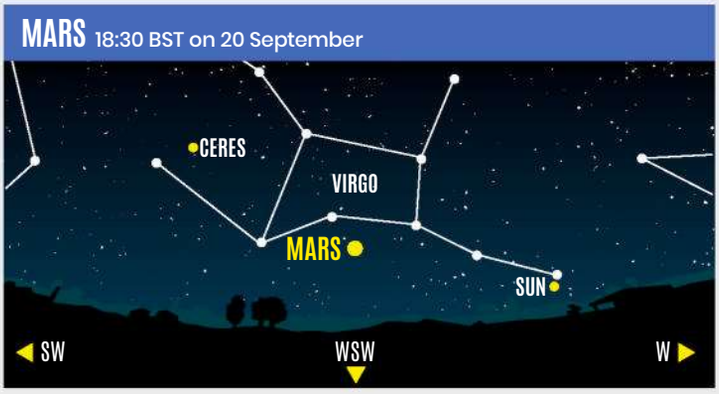
MERCURY 06:46 BST on 5 October



Constellation: Leo **Magnitude:** -0.1 **AM/PM:** AM

Mercury will be a copper-hued 'star' visible to the naked eye before sunrise, shining to the lower left of brighter Venus. At the start of this period it will rise some 45 minutes before the Sun, but it will be best seen around the turn of the month, when it will have crossed the border into Virgo and will rise 90 minutes before the Sun.

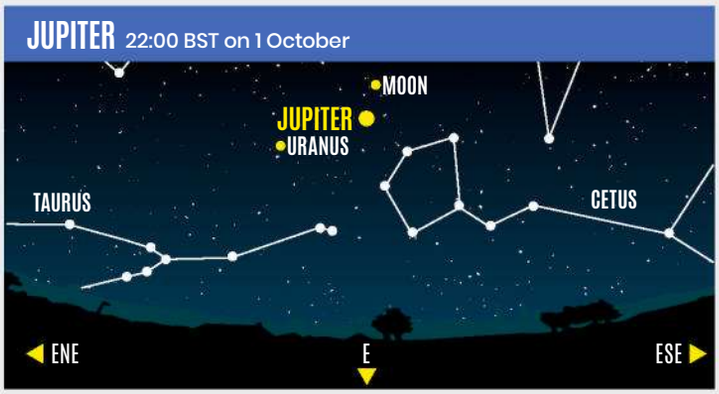
MARS 18:30 BST on 20 September



Constellation: Virgo **Magnitude:** +1.8 **AM/PM:** PM

As the Sun sets, Mars will already be very low in the west – so low that it will almost certainly be hidden behind any trees, buildings or hills on your western skyline. It will set less than half an hour after the Sun, making it very challenging to see, and you'll need binoculars to track it down.

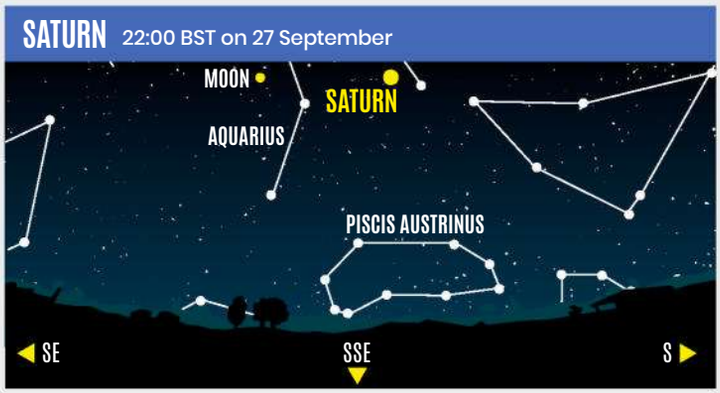
JUPITER 22:00 BST on 1 October



Constellation: Aries **Magnitude:** -2.4 **AM/PM:** PM

This month Jupiter will be a bright blue-white 'star' shining to the right of the beautiful Pleiades star cluster and will be visible to the naked eye from late in the evening through to dawn. In early September it will rise around 22:00, and by the start of October will be rising around 20:00, making it visible all through the night.

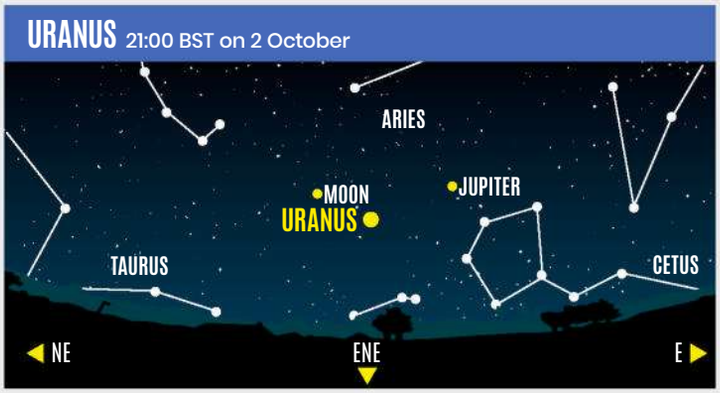
SATURN 22:00 BST on 27 September



Constellation: Aquarius **Magnitude:** +0.6 **AM/PM:** PM

At the start of September Saturn rises in the east at the same time as the Sun sets in the west, so it will be visible all through the evening. By the start of October it will rise before sunset, giving you longer to see it. Look out for the brilliant full Moon shining to the left of Saturn after dark on the evening of 27 September.

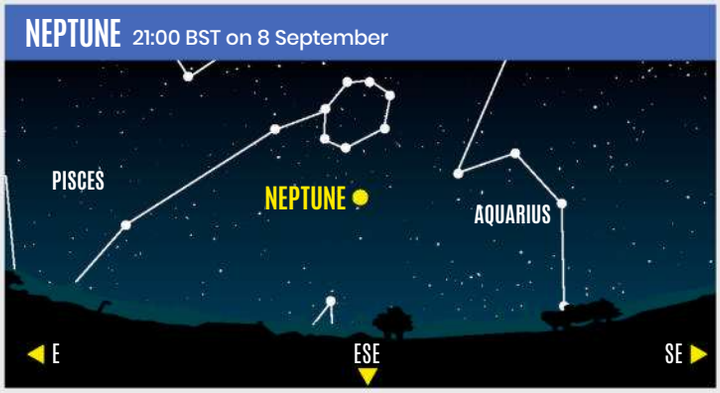
URANUS 21:00 BST on 2 October



Constellation: Aries **Magnitude:** +5.8 **AM/PM:** PM

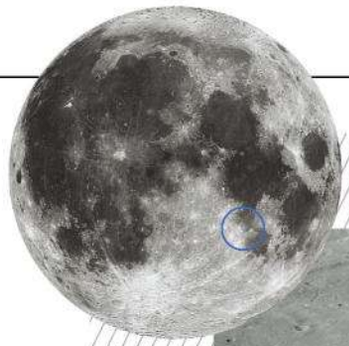
At the start of September Uranus will already be low in the east as darkness falls, and by the start of October will be rising around 20:00. After dark on the evening of 2 October a waning gibbous Moon will shine close to Uranus, on its left, directly between it and the Pleiades star cluster, making it a little easier to identify.

NEPTUNE 21:00 BST on 8 September



Constellation: Pisces **Magnitude:** +7.8 **AM/PM:** PM

Neptune is so far away that it's not visible to the naked eye. At the start of September it will rise at sunset, making it visible all through the evening to those with telescopes. It will be slightly easier to track down on the evening of 8 September, when an almost-full Moon will be shining just two-and-a-half degrees away from it.



MOON TOUR

THEOPHILUS

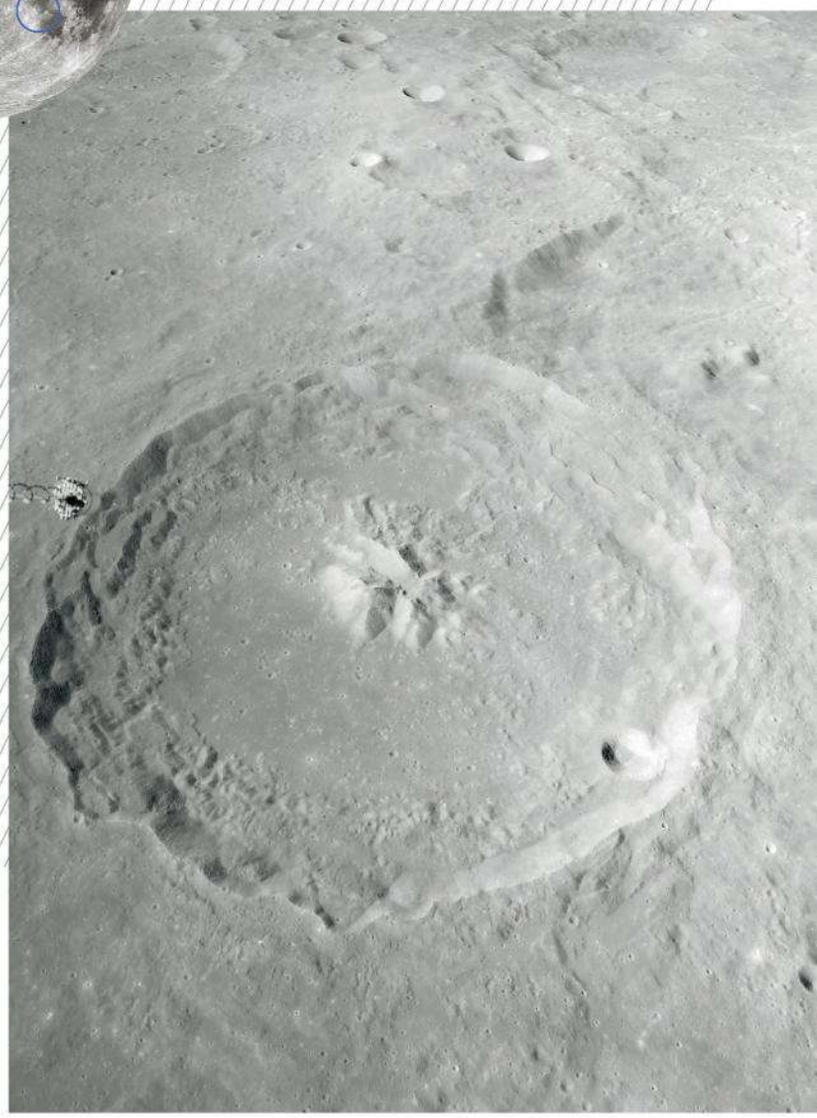
How to find one of the most striking but overlooked craters on the lunar surface

Lunar observers often feel frustrated during summer because the Moon's low altitude means they have to see it through the murk and haze that lingers above the horizon, so the Moon often appears bloated and its image wobbles and warps in eyepieces. But the Moon is always a lovely sight through a telescope, so why not try and track down something you'll almost certainly have seen before but not spent time looking at properly.

Set between the dark stain of Mare Nectaris to the southeast and Sinus Asperitatis in the north, Theophilus is one of the most striking craters on the whole of the Moon – or at least on the side that faces us. Named after the 23rd Pope of Alexandria, who made no friends in religious circles by ordering the slaying of 10,000 monks, the crater is best seen during the lunar month for four or five days after new Moon and just before it reaches last quarter, when it lies close to the terminator. During full Moon Theophilus' features are washed out. It then looks more like a white smoke ring than a pit, but is still easy to see.

Theophilus is a classic 'Tycho-class' impact crater, deep and round, closely resembling better known 'celebrity' craters like Copernicus, Eratosthenes and Tycho itself. Roughly 100 kilometres (62 miles) wide and 3.2 kilometres (1.9 miles) deep, Theophilus' floor is flat because it was flooded with lava after its formation, but since then it has been spattered with numerous smaller craters.

The largest of these, 'Theophilus B' is eight kilometres (4.9 miles) wide and was blasted out of the crater's northwestern wall. A clover-leaf cluster of four 1.4-kilometre (0.8-mile) high mountainous peaks rises up from Theophilus' smooth floor. High magnifications show the four peaks looking like a single peak hacked into four separate pieces; when the Sun's light strikes them at low angles, the tallest two peaks cast dramatic triangular shadows across the western side of the crater floor.



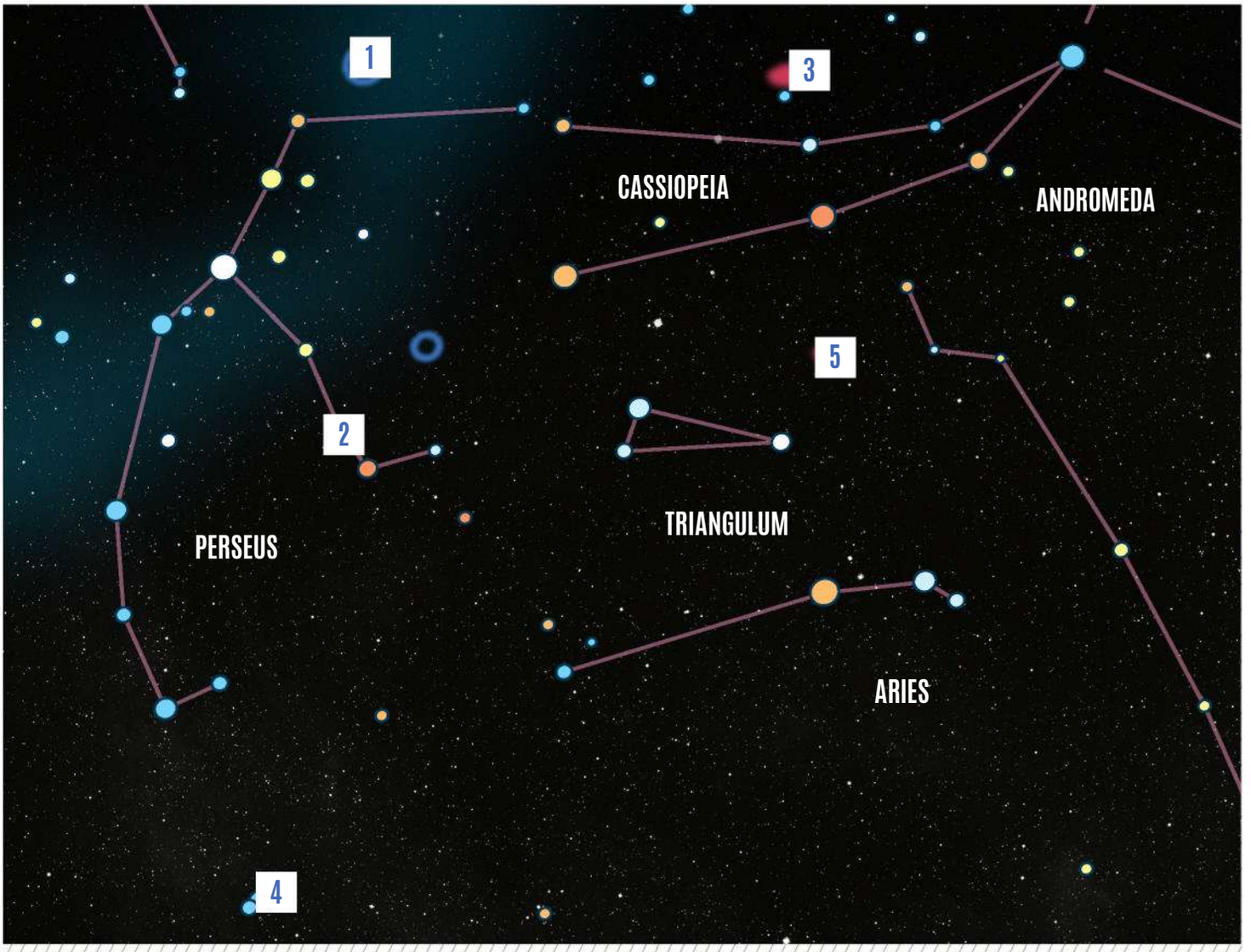
TOP TIP!

The best time to see Theophilus is when it is near the terminator. That's when it looks most dramatic through a telescope.

Like many of the other great lunar craters, Theophilus forms one half of a striking double crater. It was formed by an impact which obliterated the northeastern corner of an existing crater, Cyrillus. Unlike Tycho, however, no major ejecta rays can be seen stretching away from Theophilus, not even at full Moon when such rays tend to jump out at us. We know that a huge amount of material was scattered across the Moon when it was formed because some of it was found almost 3,000 kilometres (1,864 miles) away when the crew of the penultimate Apollo mission, Apollo 16, explored and gathered samples from their landing site in the Descartes Highlands in 1972.

Like many other craters its size, Theophilus has a sharp rim and gently sloping walls. These are broken up with terraces, ledges and shelves on the eastern side, while much of the floor on the crater's western side has been covered by landslides. In early September, with the Moon a waning crescent, Theophilus is in total darkness. It won't be visible at all until the evening of 21 September, when the terminator, the line between lunar day and night, sweeps over it again just before first quarter. For the next couple of evenings the crater will appear at its most dramatic as the Sun's low-slanting rays cast stark shadows behind and within it. When the Moon reaches full on 29 September, Theophilus will be fully illuminated from the Sun blazing overhead and will show virtually no surface relief, reduced to a light coffee cup ring. By 3 October the great crater will become prominent again as the Moon begins to wane and the terminator approaches it once more. The terminator rolls over the crater again on 4 October and we will lose sight of it as it is plunged into darkness.

© NASA



NAKED EYE AND BINOCULAR TARGETS

Find galaxies, beautiful star clusters and a demonic star on crisp autumn nights

1 The Double Cluster (NGC 869 and NGC 884)

Look between Cassiopeia and Perseus on a clear night and you'll sense a misty smudge of light at the corner of your eye. Binoculars show this is a pair of star clusters so close together they're almost touching. But the Double Cluster is misleadingly named – one cluster is twice as far away as the other.

2 Algol (Beta Persei)

Between the Double Cluster and the Pleiades shines Algol, the second-brightest star in Perseus. It's a blue-white variable star that appears to brighten and fade every three days. Algol's nickname, 'the Demon Star', is very appropriate, as it represents an eye winking in the severed head of the Gorgon Medusa.

3 Andromeda Galaxy (Messier 31)

If you have good eyesight, you'll see a misty smudge out of the corner of your eye between the Double Cluster and the Square of Pegasus. Binoculars show the Andromeda Galaxy as a lens-shaped smear of light about as wide as the full Moon, and it glows at a magnitude of +3.44.

4 The Pleiades (Messier 45)

Known as a winter object, the Pleiades star cluster can be spotted low in the sky after dark this month. To the naked eye, Messier 45 – also dubbed the Seven Sisters – looks like a fingernail-sized knot of stars. Binoculars show it as a beautiful spill of blue-white diamonds in the shape of a mini Big Dipper.

5 Triangulum Galaxy (Messier 33)

Although technically bright enough to see with the naked eye, Messier 33 isn't anywhere near as large or as obvious as Messier 31. However, on the clearest Moon-free night this spiral galaxy is visible, appearing as a small, misty patch in 10x50 binoculars from 3 million light years away.

4 The Wizard Nebula (NGC 7380)

DEEP SKY CHALLENGE

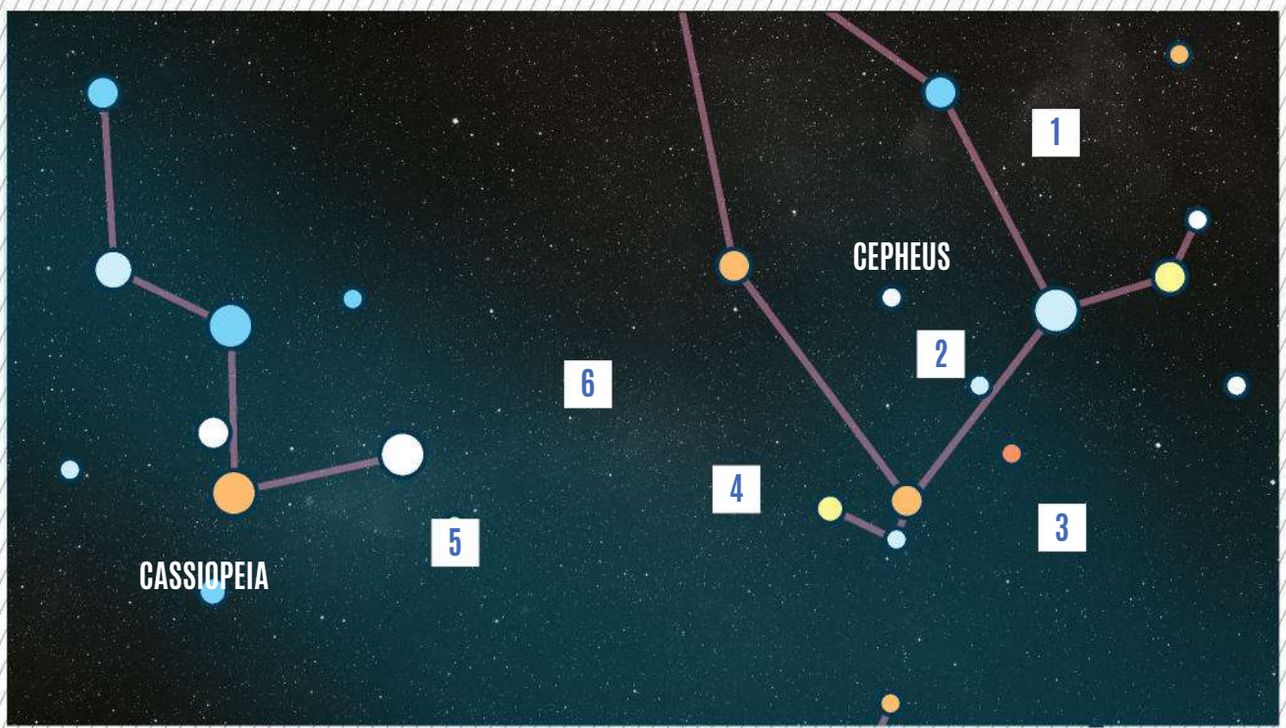
TREASURES OF THE AUTUMN MILKY WAY

Among the richest for deep-sky observers, September brings star clusters, nebulae and galaxies galore

The Milky Way, that ribbon of light that's part of a spiral arm of our own galaxy, is still well on show during late September and early October. This means that a lot of deep-sky objects either embedded in it or near to it are also on display.

High up in the sky from mid-northern latitudes, the constellations of Cepheus (the King) and Cassiopeia (the Queen) can be found sweeping around the north celestial pole throughout the course of the night. The pair of royal star patterns are full of star clusters and nebulae easily available to even the most modest of amateur telescopes. Within this region of sky there are some challenges for those with telescopes with even larger apertures. The Elephant's Trunk Nebula (IC 1396), for example, has a star cluster associated with the nebula which is relatively easy to see, but it's the surrounding gas and dust that's much more challenging to detect. Whatever you choose to look at, you can enjoy the delights of the early autumn skies.

6 Messier 52



© NASA; Source: Wikipeida Commons © Hewholooks/Luc Viatour

1 The Iris Nebula (NGC 7023)

A bright reflection nebula lit up to magnitude +6.8 by a star cluster at its centre, it requires an instrument with an aperture of at least ten inches to pick out details beyond a faint, misty patch.

2 NGC 7160

A small but attractive open star cluster, NGC 7160 can be picked up under moderate magnification. The cluster is quite sparse. However, its member stars are noticeably bright-white diamonds.

3 The Elephant's Trunk Nebula (IC 1396)

If you look carefully through your telescope of at least a medium to large-sized aperture, you can locate a dark, dense globule known as IC 1396A which gives the nebula its name.

4 The Wizard Nebula (NGC 7380)

Here's another tricky-to-spot nebula with a small star cluster nestled at the centre. In order to pick out the details of the Wizard Nebula, it's likely that you'll need a filter, such as an OIII.

5 Caroline's Rose (NGC 7789)

This lovely star cluster does look like a rose seen from above. It's located among the rich starfields of the Milky Way towards Cassiopeia, so will require a trained eye and telescope in order to spot it.

6 Messier 52

In the constellation of Cassiopeia is this large open star cluster that's easy to locate in even a small-aperture telescope thanks to its magnitude of +5.0 and its location in the 'W'.

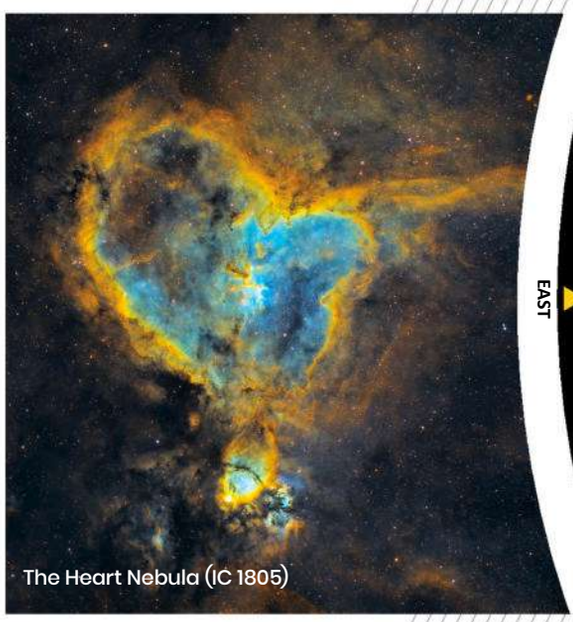
1 The Iris Nebula (NGC 7023)

NORTHERN HEMISPHERE

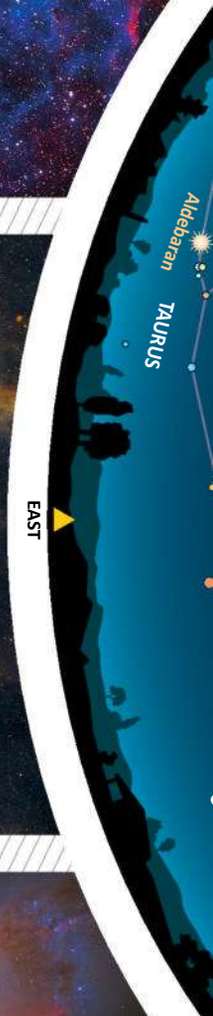
Now into autumn, the darkened skies bring some astronomical favourites

Cassiopeia (the Queen) and Cepheus (the King) lie in the dusty path of the Milky Way, offering not just a rich starfield, but impressive deep-sky objects. The Owl Cluster (NGC 457) is particularly easy to pick out with decent binoculars, its 75 to 100 bright stars forming the shape of an owl with spread wings, while the bright double star Phi Cassiopeiae comprises the celestial bird's eyes. Double star Alpha Cassiopeiae is easy to split, resolving a bright yellow primary and faint blue secondary and providing delightful views. Use the constellations of Pegasus, Aquarius and Pisces and you'll be able to locate Cetus (the Sea Monster), which contains the remarkable variable star Mira, as well as a wide selection of galaxies.

Sharpless 2-132 emission nebula


The Heart Nebula (IC 1805)

Messier 106



Using the sky chart

This chart is for use at 22:00 mid-month and is set for 52 degrees latitude.

1. Hold the chart above your head with the bottom of the page in front of you.
2. Face south and notice that north on the chart is behind you.
3. The constellations on the chart should now match what you see in the sky.

Magnitudes

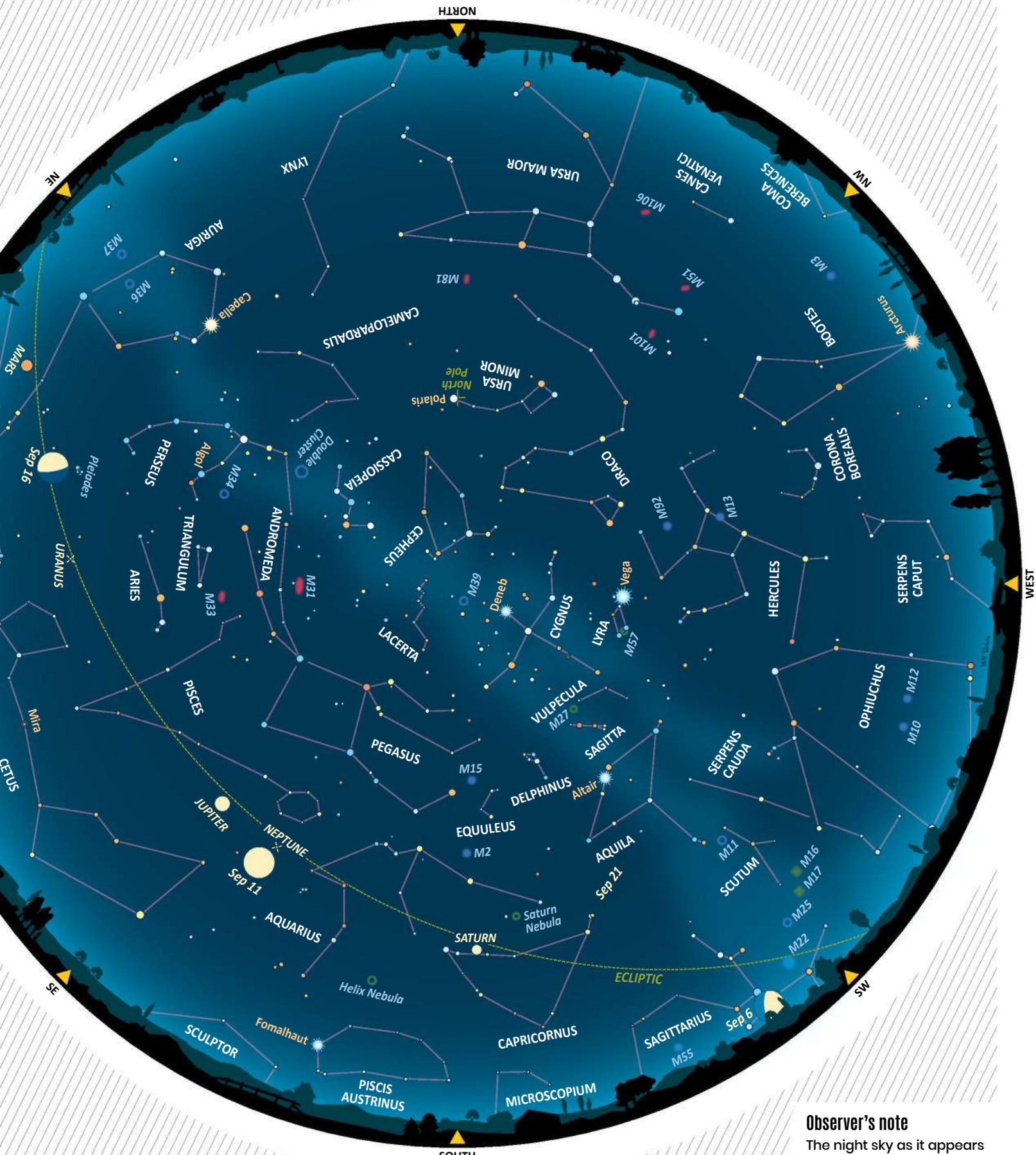
- Sirius (-1.4)
- -0.5 to 0.0
- 0.0 to +0.5
- +0.5 to +1.0
- +1.0 to +1.5
- +1.5 to +2.0
- +2.0 to +2.5
- +2.5 to +3.0
- +3.0 to +3.5
- +3.5 to +4.0
- +4.0 to +4.5
- Fainter
- Variable star

Spectral types

- O-B
- A
- F
- G
- K
- M

Deep-sky objects

- Open star clusters
- Globular star clusters
- Bright diffuse nebulae
- Planetary nebulae
- Galaxies



Observer's note
The night sky as it appears on 17 September 2023 at approximately 22:00 (BST)

© Getty

REVIEW

VAONIS VESPERA OBSERVATION STATION

Smart and fully automated, the Vaonis Vespera Observation Station is a telescope and camera rolled into one

Reviewed by Gemma Lavender

DETAILS

Cost: £1,299 / $1,499
Size: 38.1 by 20.3 by 8.9 centimetres (15 by 8 by 3.5 inches
Aperture: Two inches
Focal length: Eight inches
F ratio: f/4
Field of view: 1.6 by 0.9 degrees
Imaging sensor: Sony IMX462
Magnification: 30x
Weight: Five kilograms

The Vaonis Vespera is switched on via the button on the side

The Vaonis Vespera is your all-in-one ticket to becoming an astrophotographer. Unlike ordinary telescopes, the Vespera doesn't have an eyepiece, so you can't look through it. Instead the Vespera contains a built-in imaging sensor that captures images of whatever it's pointed at, which you can view directly on your smartphone or tablet, which you also use to control the Vespera with Vaonis' Singularity software. It sports a two-inch f/4 quadruplet apochromat telescope, which means it's designed around two sets of two lenses that remove chromatic aberration. At the same time it hosts a 2.1-megapixel Sony Starvis IMX462 CMOS camera sensor for recording the Vespera's clarity of view.

Vaonis launched its first imaging telescope, the Stellina, in 2018, and the Vespera builds on that experience while also providing more portability. It has a smaller aperture and imaging sensor than the Stellina, meaning it doesn't reach the same level of resolution that the Stellina achieves, but the price is less than half that of the Stellina, making the Vespera extremely tempting. The sheer enjoyment that we got out of straightforward imaging and then being able to share those images with others logged onto the Vespera's Wi-Fi network is addictive. We found the Vaonis Vespera to be great fun, and it only fails to achieve top marks because of its lack of accessories, its somewhat limited versatility and because its sibling, the Stellina, is technically a more powerful instrument.

The Vespera doesn't look like your typical telescope. It looks a bit like an egg, and when we pressed the 'on' switch at the side of the instrument, half of it folded out – this was the telescope part, attached to a single arm. Two inches of aperture isn't much, and if this were a visual telescope with an eyepiece it would be too small. For imaging,

The Vaonis Vespera with the Vaonis light-pollution filter, which unfortunately is an optional extra

The hygrometer, light-pollution filter and solar filter are all of high quality, but have to be bought separately

"For all the hype, the Vespera had a lot to live up to, and thankfully we think it did so brilliantly"

BEST FOR...

- LARGE BUDGETS
- FAMILIES
- BEGINNERS
- ASTROPHOTOGRAPHY
- DEEP SKY

where photons build up incrementally to form a picture, it's a different matter. At f/4 and a focal length of 7.8 inches, wielding a field of view of 1.6 by 0.9 degrees on the sky, it's capable of imaging large deep-sky targets, the Moon and, with the separate purchase of Vaonis' full-aperture solar filter, the Sun. The field of view is sadly too big for planetary imaging. Resolution is three arcseconds per pixel, which while not brilliant is more than enough to capture wonderful images of galaxies and nebulae.

Weighing less than five kilograms, the Vespera is easily portable for when you want to get away to those dark-sky locations. The package comes with a tiny tabletop tripod that we had to assemble ourselves by screwing in the legs, but the thread that attaches the Vespera to the tripod should also fit many larger photographic tripods. Vaonis also offers its own larger tripod for an additional cost.

For all the hype, the Vespera had a lot to live up to, and thankfully we think it did so brilliantly. Once activated, the Vespera creates its own Wi-Fi network that we could connect to our smartphone – or tablet, if that's what you use – while running the Singularity app, which we downloaded to our device via a QR code. Our first job was to input our location into the app so that the telescope knows its latitude and longitude and where the stars are positioned in the sky relative to its location. You then press a button on the app to initialise the Vespera – although we could do that, we first had to download an update to the software. Once initialised, the Vespera then scans around the sky, looking for patterns of stars that it can match up to charts stored in its memory to figure out where it's pointing and the orientation of the sky. It then automatically focuses itself. The focusing was perfect, with pinpoint stars.

The Vespera is controlled entirely by Singularity. The app provides basic information, such as the phase of the Moon and when the Sun rises and sets, and it flags up some celestial highlights that are especially helpful for beginners who may not know where to start. But it was the imaging that we were here for. The first target we selected was NGC 7000, the North America Nebula in the constellation of Cygnus. It took about a minute for the telescope to swivel on its base and move its telescope arm up to point at the nebula. Then, once it was ready to begin capturing the image, the app displayed a kind of space warp effect before the image appeared. The Vespera stacks new images every 20 seconds – though this exposure time can be adjusted in the options – and we could just see the red outline of the nebula beginning to fill the field of view as clouds began to roll in. Though forced to abandon that image, it was noticeable how the nebula's two-degree-wide expanse was a little too big for the Vespera's field of view. However, Singularity has a mosaic mode that allows you to image up to four times the normal field of view by joining different exposures together. When this is employed, the North America Nebula can be captured in its entirety.

Undeterred by the clouds, we switched to another patch of clear sky, Ursa Major, where we found two galaxies, Bode's Galaxy (Messier 81) and the Cigar Galaxy (Messier 82). Going through the motion of the telescope turning to find Messier 81, the bright, diffuse bulge of the galaxy popped out immediately Over the next ten minutes, gradually more and more of its spiral disc became apparent. It was highly impressive to watch the galaxy materialise out of the darkness. We could even zoom in and rotate

the image on our phone screen while it was still stacking.

The Cigar Galaxy was something else. Whereas Messier 81 took its time to appear, the edge-on Messier 82 showed brightly in the image after just 20 seconds, a thick dust lane in its centre apparent straight away. We were amazed by how fast the image appeared. The sliver of light grew larger and bolder, and the higher surface brightness of Messier 82 meant a much shorter total exposure time – we imaged for just five minutes. However, we did notice that the galaxies had the opposite problem to the North America Nebula – they appeared quite small in the field of view.

Taking images with the Vaonis Vespera becomes addictive, and very quickly you'll find that you can rack up more than a dozen objects in a session of a couple of hours. The brighter objects can be captured after a few dozen seconds or so, while fainter objects need longer – in the case of the ephemeral Veil Nebula a lot longer. We're talking hours, particularly if operating in mosaic mode. We chose to move on to other targets rather than wait. You can end the image capture at any time. The images are saved to folders within the app, and we could download them from there onto our device. Processing them in Photoshop or some similar product would enhance the images considerably. While we had frustrations over the field of view, overall we were really impressed by the ease with which we could image deep-sky objects, even despite the unseasonal weather.

The Vaonis Vespera package is somewhat bare-bones. Along with the instrument itself, there's a little tabletop tripod that stands just 18 centimetres (seven inches) tall and isn't really of much use, though Vaonis offers a taller tripod for additional cost. The power pack that we received only had an EU plug fitting, and we had to source our own EU-UK adaptor to use it. Battery power when fully charged lasts eight hours, though in cold winter conditions expect the battery to drain faster. The Vespera has a solar mode, but the all-important solar filter has to be purchased separately. So too does Vaonis' light-pollution filter, so if you're an urban astronomer you're going to have to deal with light-pollution gradients in your images unless you fork out for the expensive filter.

What you do get is a well-made, finely tuned and virtually flawless observation station. Every time you switch it on and the robotic arm moves into position is thrilling. The Singularity app works well and is simple to use. We liked the 'Plan Your Night' option, where we could select a list of targets and exposure times and the Vespera would automatically work its way through the list, and we wished we'd made better use of it – something that we'll be able to do now we've had more experience with the Vespera and the length of exposure times needed for certain objects. One thing that could be improved is the list of objects to choose from, which is pretty short, with no more than a few hundred objects. We're used to Go-To telescopes having catalogues of tens of thousands of objects available to observe. But if an object that we wanted to image wasn't on the list, we could manually input the right ascension and declination coordinates.

Images can be saved as JPEGs, TIFFs or raw camera files if you're intending to process them further afterwards on your home computer, which will be appreciated by dedicated astrophotographers. One cool function that we weren't able to test to its maximum is the ability for up to eight people to simultaneously join Vespera's Wi-Fi network; we did, however, link two smartphones up to it, and we think it is an excellent function, particularly for astronomical outreach at public events and star parties. Indeed, its ease of use makes the Vaonis Vespera a perfect device for beginners.

Purely visual observers might automatically recoil at the idea of a telescope without an eyepiece where you can only do imaging, but we recommend that even visual observers give the Vaonis Vespera a shot. It's addictive fun and very quickly you can build up a library of astroimages to show your friends and family and share on social media. However, the asking price of £1,299 ($1,499) is a hefty chunk of cash for casual users.

It's also quite an expensive way to get into astroimaging. If you already own a telescope in the four to eight inch category or larger, then the price of a CCD, CMOS or DSLR camera and a Go-To equatorial mount isn't going to come to more than the price of the Vespera, unless you go really high-end. However, that kind of hands-on imaging requires a degree of know-how: the use of filters if you're using a mono camera, stacking and the other various processing stages, and they all require a computer. If you don't have a computer, or don't feel skilled enough to master the processing steps, then the instant results of the Vespera might be attractive to you. In a way it's the astronomical version of a Polaroid camera.

This ability to produce instant results, as well as the multi-user mode, is where the Vespera really shines, and it's sure to be a crowd-pleaser at star parties, outreach events, schools or family gatherings. If you're involved in education or outreach work presenting the night sky to children or members of the public, then we think the Vaonis Vespera is an essential instrument.

The Vaonis Vespera is fun, but it's not versatile. Planetary imagers wanting to do close-up work need a much smaller field of view. A Schmidt-Cassegrain telescope such as the Celestron Advanced VX 8" EdgeHD would be more suitable, coupled to an equatorial Go-To mount and using a Canon EOS R8.

FOR

- Easy to use
- Almost instant images
- Can share with up to eight people on Wi-Fi

AGAINST

- Expensive
- Important accessories must be bought separately
- Large field of view prevents serious planetary imaging

Future Genius

THE BRAND NEW

★ EDUTAINMENT ★ BOOKS FOR KIDS!

For ages 7+

OUT NOW!

Future Genius Solar System
Future Genius Cool Chemistry
Future Genius Human Body
Future Genius Animal Kingdom
Future Genius Ancient Eg
Future Genius
Future Genius COMPUTERS & Learn How To Code
Future Genius Ancient Greece
Future Genius Dinosaurs
Future Genius The Senses
Future Genius The World
Future Genius Magical Maths
Future Genius Bugs & CREEPY CRAWLIES
Future Genius The Universe

on SALE now

★ Solar System ★ Cool Chemistry ★ Human Body
★ Animal Kingdom ★ Ancient Egyptians
★ Computers & Learn to Code ★ Weather
★ Ancient Greece ★ Dinosaurs ★ The Senses
★ The World ★ Magical Maths ★ Bugs ★ The Universe

WATCH VIDEOS WITH OUR INCREDIBLE INTERACTIVE EXPERIENCE

GET YOURS NOW FROM MAGAZINESDIRECT.COM
AND ALL GOOD SUPERMARKETS AND NEWSAGENTS

✚ Puzzles ✚ Activities ✚ Experiments ✚ Facts ✚ More!

IN THE SHOPS: RED-LIGHT HEADLAMPS

Here's our round-up of the best headlamps to keep your hands free and give you visibility in the dark

3

1

2

Nitecore HC65 V2

Cost: £89.95 / $84.95
From: Nitecore

1 The brightest light here can shine at 1,750 lumens and gives you a 165-metre (541-foot) beam. It has been designed to preserve battery life and runs for 28 hours on a single charge on its lowest setting of 50 lumens, as opposed to the predecessor HC65, which ran for 16 hours on a single charge. It has five brightness levels and three light sources. It uses a USB C port for charging, which is now more common than the micro USB found on other models, and it also charges quicker. You can remove the battery, so you have the option of taking multiple charged batteries and swapping them if you need to. It's on the more expensive end of this list, but having full metal housing, a submersible waterproof rating and impact-resistant qualities, it will last for years. What's more, it's ideal for those clumsier astronomers among us or those who partake in more extreme activities alongside astronomy and astrophotography.

Vont Spark LED Headlamp

Cost: £17.99 / $13.99
From: Vont

2 For a very easy-on-the-wallet headlamp, this is versatile and good quality. What's more, it comes with a lifetime warranty for peace of mind. This two pack comes with a set of batteries, which makes it even better value. The Vont Spark has seven different lighting settings, activated by cycling through. The red light is activated by holding the button down for three seconds, then cycling between low, strobe or SOS mode. Once the selection has been made and left on for an extended period, the headlamp will allow the user to turn it off with one touch, meaning you don't have to cycle through all the modes. It has a comfortable headband and a 45-degree tilt so you can pivot the angle of the beam to suit your preference. You'll need three AAA batteries to power the headlamp, although they do last for a good amount of time. It's also waterproof, which is a huge plus, rated to IPX5, meaning it's protected against low-pressure streams from any angle, which includes rain.

WindFire Headlamp

Cost: £29.99 / $28.99
From: WindFire

3 Here we have another red-light exclusive headlamp, and this headtorch shouldn't be overlooked. Unlike some of the other models where you have to remove the batteries to charge them, the WindFire has a slot for USB charging, meaning you can charge it from a power bank, car or mains before your trip. It has a generous 90-degree pivoting mount that helps you see the ground right in front of you. The beam is zoomable, so you can adjust it as necessary for close-up work or finding your way back to your vehicle. WindFire offers a 30-day full refund and a 12-month warranty for extra assurance, which is a nice fallback with a less established brand.

"No one wants to trip when carrying expensive astrophotography equipment"

BioLite HeadLamp 330

Cost: £59.99 / $59.95
From: BioLite

4 This headlamp is so tiny you'll soon forget you have it on. It fits flat to the forehead and has a 'no-bounce' design that is predominately handy for runners, but also means it won't be in the way of you peering into a telescope or viewfinder. Its fabric is made from an absorbent wicking to keep your forehead comfortable and dry – again this is a design that's most intended for runners, but will make extended use more comfortable for anyone. The reflective strip on the headband will make you more visible to others and will also make it easier to find in the dark. The front bezel of the headlamp articulates to adjust the light to your desired angle. It's rechargeable via micro USB and also has a battery indicator to show how much power remains so you don't get caught out and find yourself left in the dark. You can charge it while using it, which is a bonus, especially if you're retiring back to your dark tent as you can continue using it while you charge it with a power bank.

Actik Core 450

Cost: £60 / $69.95
From: Petzl

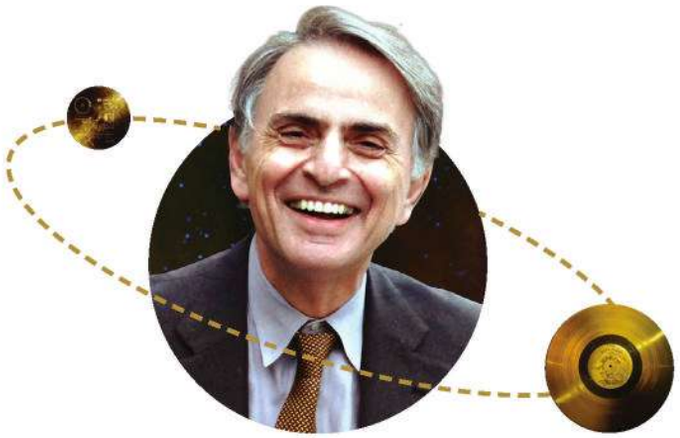
5 In the world of headlamps, Petzl is a known and trusted brand for quality and reliability, and you get exactly that with this headlamp. The manufacturer has been evolving its headlamps for over 40 years, and you get a five-year lamp and a two-year battery guarantee. The headlamp has a rechargeable battery but can also take three regular AAA batteries. That's a handy feature to have, especially if you've forgotten to recharge before use. We like that we can plug the charger straight into the battery without having to remove it from the case and strap – less likelihood of losing something. The only downside is that you can't use the torch while charging, but that's a little detail and we're being picky. It has an incredibly bright white beam to help you get to your location if out in the field, but if you long-press the single button you'll get to the red light. The button is ergonomic and responsive, so it can easily be operated with gloves on cold nights.

Black Diamond Storm 400

Cost: £45 / $49.95
From: Black Diamond

6 The Storm 400 is a versatile headlamp that uses PowerTap technology to switch between maximum brightness and the dimmed setting with one movement. This sounds like it would be detrimental, but in reality the PowerTap feature requires around a second's worth of contact between your finger and the surface, so it shouldn't cause you any trouble. It also has a memory feature, so it will turn back on at the brightness level you left it. The Storm 400 is IP67 rated, making it completely protected from dirt and dust ingress, and is waterproof in 30-minute test conditions – ideal if you're a part-time hiker, caver, climber or such. The three dimmable LEDs add versatility. The green light can make reading more straightforward, which might be helpful if you have to read an instruction manual or a map to get to your location. It takes four AAA batteries, so we'd recommend getting yourself a charger and some rechargeable batteries to keep long-term costs down.

HEROES OF SPACE



CARL SAGAN

From giant stars to the smallest mote of dust, Sagan helped popularise space like never before

Sagan was born on 9 November 1934 in New York. It was at the 1939 New York World's Fair where he first encountered science and astronomy. His imagination was captured by a time capsule containing memories of the 1930s that was buried for future generations to uncover, and this inspired him to create the Pioneer plaque and Voyager Golden Records – memories of Earth that would be sent far into the cosmos aboard their respective spacecraft. His interest in space led him to the University of Chicago, where he achieved a PhD in astronomy and astrophysics. Throughout the 1950s he worked as an adviser to NASA, which included briefing the Apollo astronauts and working on experiments for the Galileo and Voyager spacecraft, among others.

Some of his major scientific achievements occurred in the 1960s, starting with his conclusion that Venus was a scorching world with a thick atmosphere, rather than a moderate Earth-like paradise. This theory was proved correct by Mariner 2 in 1962. He was also one of the first scientists to suggest that Saturn's moon Titan might have liquids on its surface, and he helped study shifts in surface dust on Mars. Some of his most famous research concerned extraterrestrial life, which he was sure existed.

For all his scientific research, it was through television that he rose to fame. His most famous show was arguably the 13-part *Cosmos: A Personal Voyage*, hosted and co-written by Sagan, which covered topics including the origins of life on Earth and our place in the universe. Having been broadcast in over 60 countries and seen by more than half a billion people, it remains one of the most popular space-related television shows to date. As well as his television appearances, he wrote a number of books, including *Pale Blue Dot: A Vision of the Human Future in Space*, which was inspired by the image of Earth taken by the Voyager 1 spacecraft – at Sagan's behest - that showed Earth as a "mote of dust suspended in a sunbeam."

Despite his widespread fame, he stayed devoted to teaching, remaining as a professor of astronomy at Cornell University until his death on 20 December 1996. Among his notable posthumous recognitions, the landing site for NASA's Mars Pathfinder spacecraft was renamed the Carl Sagan Memorial Station in July 1997, while 'Sagan's number' is a humorous tribute to his catchphrase "billions and billions", which denotes the huge number of stars in the universe. Forever remembered for making space accessible to everyone, it feels fitting to end on one of his awe-inspiring statements: "The total number of stars in the universe is larger than all the grains of sand on all the beaches of the planet Earth."

ALL ABOUT SPACE ISSUE 148

ON SALE 5 OCT

© Alamy; NASA

ALL ABOUT SPACE

Future PLC Quay House, The Ambury, Bath, BA1 1UA

Editorial
Editor **Gemma Lavender**
gemma.lavender@futurenet.com
Art Editor **Jonathan Wells**
Production Editor **Nikole Robinson**
Senior Art Editor **Duncan Crook**

Contributors
Stuart Atkinson, Charles Q. Choi, David Crookes, Ian Evenden, Curtis Fermor-Dunman, Steven Freeland, Andrew Jones, Robert Lea, Rafael Maceira Garcia, Christopher Manser, William B. McKinnon, Tariq Malik, Belinda Nicholson, Anjali Piette, Rahul Rao, Jillian M. Scudder, Paul Sutter, Kate Underhill, Luis Villazon

Cover images
Getty; Tobias Roetsch and NASA

Photography
Alamy; ESA; ESO; NASA; Science Photo Library; Shutterstock; SpaceX; University of Arizona; Wikipedia Commons
All copyrights and trademarks are recognised and respected

Advertising
Media packs are available on request
UK Commercial Director **Clare Dove**
clare.dove@futurenet.com
Advertising Sales Director **Lara Jaggon**
lara.jaggon@futurenet.com
07515 961 911
Account Manager **Hayley Brailey-Woolfson**
hayley.baileywoolfson@futurenet.com
01643 678 054

International Licensing and Syndication
All About Space is available for licensing and syndication. To find out more contact us at **licensing@futurenet.com** or view our available content at **www.futurecontenthub.com**.
Head of Print Licensing **Rachel Shaw**
licensing@futurenet.com

Subscriptions
Enquiries **help@magazinesdirect.com**
UK orderline & enquiries **0330 333 1113**
Overseas orderline & enquiries **+44 (0)330 333 1113**
Online orders & enquiries **www.magazinesdirect.com**
Group Marketing Director, Magazines & Memberships **Sharon Todd**
Disruption remains within UK and international delivery networks. Please allow up to seven days before contacting us about a late delivery at **help@magazinesdirect.com**

Circulation
Head of Newstrade **Ben Oakden**

Production
Head of Production **Mark Constance**
Production Project Manager **Clare Scott**
Senior Advertising Production Manager **Jo Crosby**
Digital Editions Controller **Jason Hudson**
Production Manager **Nick Williams**

Management
SVP Lifestyle, Knowledge and News **Sophie Wybrew-Bond**
Managing Director **Chris Kerwin**
Editor-in-Chief **Timothy Williamson**
Head of Art & Design **Greg Whitaker**

Printed by William Gibbons & Sons Limited, 26 Planetary Road, Willenhall, Wolverhampton, West Midlands, WV13 3XB

Distributed by Marketforce, 5 Churchill Place, Canary Wharf, London, E14 5HU **www.marketforce.co.uk**

ISSN 2050-0548

All contents © 2023 Future Publishing Limited or published under licence. All rights reserved. No part of this magazine may be used, stored, transmitted or reproduced in any way without the prior written permission of the publisher. Future Publishing Limited (company number 2008885) is registered in England and Wales. Registered office: Quay House, The Ambury, Bath BA1 1UA. All information contained in this publication is for information only and is, as far as we are aware, correct at the time of going to press. Future cannot accept any responsibility for errors or inaccuracies in such information. You are advised to contact manufacturers and retailers directly with regard to the price of products/services referred to in this publication. Apps and websites mentioned in this publication are not under our control. We are not responsible for their contents or any other changes or updates to them. This magazine is fully independent and not affiliated in any way with the companies mentioned herein.

If you submit material to us, you warrant that you own the material and/or have the necessary rights/permissions to supply the material and you automatically grant Future and its licensees a licence to publish your submission in whole or in part in any/all issues and/or editions of publications, in any format published worldwide and on associated websites, social media channels and associated products. Any material you submit is sent at your own risk and, although every care is taken, neither Future nor its employees, agents, subcontractors or licensees shall be liable for loss or damage. We assume all unsolicited material is for publication unless otherwise stated, and reserve the right to edit, amend, adapt all submissions.

We are committed to only using magazine paper which is derived from responsibly managed, certified forestry and chlorine-free manufacture. The paper in this magazine was sourced and produced from sustainable managed forests, conforming to strict environmental and socioeconomic standards.

FUTURE
Connectors. Creators. Experience Makers.

Future PLC is a public company quoted on the London Stock Exchange (symbol: FUTR)
www.futureplc.com

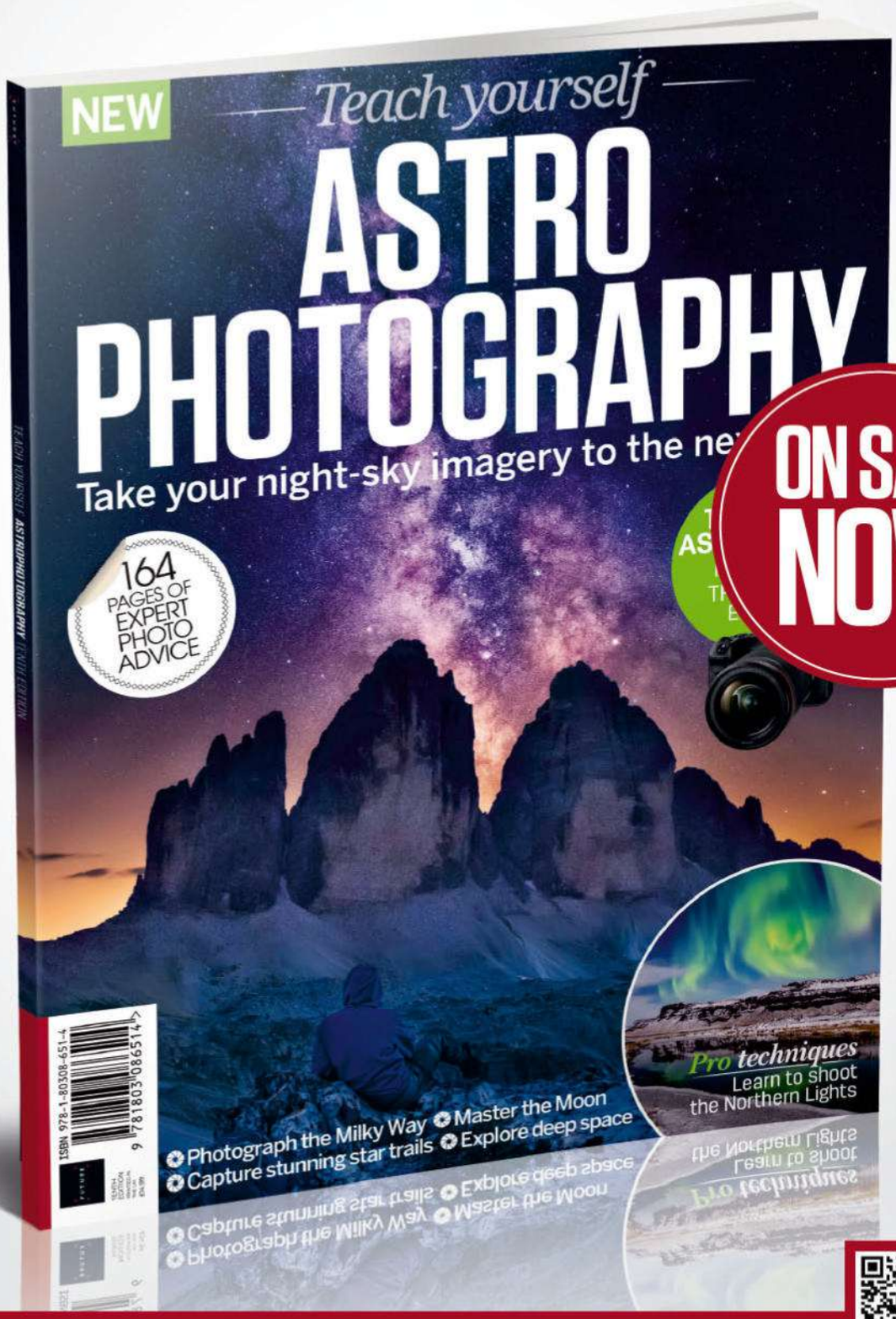
Chief Executive Officer **Jon Steinberg**
Non-executive Chairman **Richard Huntingford**
Chief Financial Officer **Penny Ladkin-Brand**

Tel +44 (0)1225 442 244

ipso Regulated

TAKE YOUR NIGHT-SKY IMAGERY TO THE NEXT LEVEL

Unearth the difference between nebula and nebulae, find out when to shoot the Moon and learn how to capture an Aurora with jam-packed features, in-depth tutorials, and all the essential kit to aid you in taking breathtaking images that are truly out of this world.



ON SALE NOW

FUTURE

Shop easily online at:

magazinesdirect.com

bit.ly/3RQ81Hu

Sky-Watcher®

Be amazed.

POPULAR BEGINNER & INTERMEDIATE TELESCOPES

"This telescope made observing the night sky enjoyable....great views coupled with ease of use"
BBC SKY AT NIGHT MAGAZINE

Sky at Night MAGAZINE GROUP TEST WINNER

ASTROLUX
76mm f/9.2 REFLECTOR

Sky at Night MAGAZINE GROUP TEST WINNER

MERCURY-705 (AZ3)
70mm f7.1 REFRACTOR
SRP £159

CAPRICORN-70 (EQ1)
70mm f/12.8 REFRACTOR
SRP £139

"Meets all expectations and is the perfect starter scope"
BBC SKY AT NIGHT MAGAZINE

EXPLORER-130 (EQ2)
130mm f/6.9 REFLECTOR
SRP £199

SKYHAWK-1145P (EQ1)
114mm f/5 PARABOLIC REFLECTOR
SRP £179
SRP £109

EXPLORER-130P (AZ-GO2)
130mm (5.1") f/5 Wi-Fi GO-TO Parabolic Reflector
SRP £339

SKYHAWK-1145P (AZ-GO2)
114mm (4.5") f/4.4 Wi-Fi GO-TO Parabolic Reflector
SRP £399

SKYMAX-127 (AZ-GO2)
127mm (5") f/11.8 Wi-Fi GO-TO Maksutov-Cassegrain
SRP £529

SRP £649

SKYMAX-127 (AZ-GTI)
127mm (5") f/11.8 Wi-Fi GO-TO Maksutov-Cassegrain

Sky at Night MAGAZINE ★★★★★ REVIEWED IN Issue 152 January 2018

STAR DISCOVERY P150I 150mm (6")
f/5 Wi-Fi GO-TO Parabolic Reflector
SRP £599

EXPLORER-150PL (EQ3-2)
150mm f8 PARABOLIC REFLECTOR
SRP £399

Sky at Night MAGAZINE GROUP TEST WINNER

EXPLORER-200P (EQ5)
200mm f/5 PARABOLIC REFLECTOR
SRP £749

SKYLINER-200P CLASSIC
203mm f/5.9 PARABOLIC DOBSONIAN

Sky at Night MAGAZINE HIGHLY COMMENDED 93%

SRP £449

SKYLINER-250P CLASSIC
254mm f/4.7 PARABOLIC DOBSONIAN
SRP £659

HERITAGE-150P FLEXTUBE™ (VIRTUOSO GTI)
150mm f/5 Wi-Fi GO-TO PARABOLIC DOBSONIAN
SRP £449

SKYMAX-127 (VIRTUOSO GTI)
127mm f/11.8 Wi-Fi GO-TO MAKSUTOV-CASSEGRAIN
SRP £599

SRP £219

HERITAGE-130P FLEXTUBE™
130mm f/5 PARABOLIC DOBSONIAN

SRP £289

HERITAGE-150P FLEXTUBE™
150mm f/5 PARABOLIC DOBSONIAN

STAR ADVENTURER MINI PRO PACK
STAR TRACKER

Sky at Night MAGAZINE ★★★★★ REVIEWED IN Issue 143 April 2017

SRP £269

Wi-Fi

DSLR & Tripod not included

Available from dealers throughout the UK

OPTICAL VISION LIMITED

Full product details at:
www.opticalvision.co.uk
info@opticalvision.co.uk

9021

9000